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ICHTHYOLOGY.—*Salmon psychology.*[1] HENRY B. WARD, University of Illinois. (Communicated by CHARLES E. CHAMBLISS.)

Many years ago I became interested in the salmon and its remarkable life history. Good fortune brought me in personal contact with that great student of American fishes, David Starr Jordan, whose work on the Pacific salmon is well known. His discussions further stimulated my interest and I was able to enter on a series of field studies which has extended over more than 25 years. This work has been intensive rather than extensive and has taken a different direction from that of most of those who have been active in this field hitherto. From the start it has been rather strictly limited in that it was confined primarily to a single species of Pacific salmon, the sockeye or red salmon (*Oncorhynchus nerka*), and to that part of its life cycle spent in fresh water. I have been able to carry on this study at several widely separated places and incidentally to accumulate also scattered information concerning related species and genera which has afforded a valuable check on my own more extended observations of the red salmon.

Desiring to secure the most intimate contact possible with the species, I have spent the summer months following the adults from river mouth to spawning ground, endeavoring to determine just what they did and why under varying conditions of stream, climate, and weather. The tales and interpretations of tourists, natives, fishermen, and Indians were welcomed and subjected to impartial scrutiny in the task of sifting some truth from the mass of error and fancy that always pervades popular accounts of animal life. This combination of personal observations with explanations of others has in the course of time given an intimate knowledge of the fish in its environment sufficient to justify calling this address a study of salmon psychology. It is presented with full recognition of its incompleteness and imperfections, as a basis for directing attention to a somewhat neglected aspect of the study of the salmon.

[1] Address delivered before the Washington Academy of Sciences, December 17, 1936. Received November 29, 1938.

Extensive studies on various types of animals have shown the existence of internal or functional influences and also of external or environmental influences as controlling or directing factors in animal activities. Internal influences are undoubtedly as real and as powerful in fish as in other types of animal life. They are however not discussed here. The purpose of my early studies has been to ascertain how far and in what way the activities of the Pacific salmon in fresh water are determined or modified by external factors. To do this it was necessary to collect by careful and extended study a considerable volume of facts and then to seek to correlate those facts with environmental conditions and the life of the fish. It seems probable that some internal or functional urge impels the adult salmon to start on its migration to the distant spawning grounds, but its exact course will be determined by series of environmental influences which at successive points condition its movements and thus determine its path. Unfortunately past observations on the fish have often been discontinuous or unrelated, and interpretations too largely anthropocentric.

The interpretation of animal activities from the standpoint of human procedure leads into serious misunderstandings. These are most apparent as one departs widely from those types of animal life which most clearly resemble man in structure and development. Nowhere is the error more frequent and more serious than in the treatment of the activities of fish. Even at the first laboratory studies on the structure of fish every student is confronted with the special development of the central nervous machinery, with the absence of the cerebrum, or fore brain, and the magnitude of the olfactory lobes. The student is impressed by the radical difference between the set-up of this system and that of man and the higher vertebrates. From it one may rightly infer that these differences indicate a basis for behavior of significantly different type. A correct knowledge of their habits also and of the underlying basis for their action in particular cases is of primary importance not only in seeking to explain the biological problems in the life history but equally in determining laws for the protection of the fish and proper methods of fish culture to increase numbers and provide against an excessive draft on the fish population in man's search for sport and food.

The study of responses to external stimuli must be made with definite precautions always in mind. First the environment is complex and one may find on analysis that the observed reaction may be due to any one of several stimuli. By extended observation or by experiment these stimuli may be separated or their particular influence

be measured. Second, different species or varieties of animals even though closely related act differently under some apparently identical conditions. Accordingly the first step towards the solution of the problem must be taken along the path of determining how one sort of salmon reacts under given conditions. It is not difficult to see in certain cases how confusion has arisen because of failure to observe these precautions.

In the interpretation of salmon activities, a multitude of influences may appear in a particular choice. One must not expect to find a single factor determining what may appear to be superficially a single choice, and the determination of the route chosen by a salmon may depend at one point upon one and at a second place upon another environmental condition. In general, the salmon running in a given stream and at a set time all make the same choice, following a route in the river system often apparently erratic and without evident reason for the preferences shown. However, the path taken by a salmon run is consistently uniform year after year and spawning grounds in a given river system are limited in number and location.

The number of elements which might possibly be involved in the choice of the route is large enough to make the basis for the series of choices difficult to determine, and some earlier observers have felt themselves forced to adopt a mystical explanation. However difficult it may be to solve the problem, the scientist is not justified in accepting this solution. All the experiments with these fish under controlled conditions and all observations of fish in nature show a definiteness of choice which may reasonably be considered to have a factual basis. The problem of the student is to determine this basis in individual cases and by extended observations to ascertain how widely similar conditions determine the same reaction.

The salmon ranks rightly as the most famous of all fish. Its life story manifests a complexity by virtue of its migration from the sea, which is the home in the active growing life period, to fresh water for the discharge of its reproductive functions. Some confusion has been introduced into the story of the salmon as told by different narrators through the combination of features from the life histories of different species of this fish. In this address attention will be directed chiefly to a single species of Pacific salmon, the sockeye or red salmon, in the effort to analyze and determine accurately the response of that fish to the stimuli acting upon it in the changing environments encountered. The life in the ocean is for the most part unknown. The full grown fish appear regularly at the surface of the sea near some river

mouth at a given season, enter fresh water streams, ascend to spawning grounds in the higher reaches, and, after discharging this function, all die. The eggs spend a winter in the gravel and the young which hatch in the spring descend gradually to the sea and there disappear, to return after a period as full-grown adults. The young sockeye does not start its journey down stream usually until the second or rarely the third spring.

Following the activities of an adult salmon in this migratory period of existence, one notes first that from the moment of entering the stream it is consistently fighting the current, always moving upward toward its goal. This response to the current stimulus contrasts positively with that of the young on the way to the sea; not swimming actively but drifting, feeding and playing, they float somewhat leisurely down the stream to salt water. While most young salmon start promptly down stream, the sockeye regularly does delay one year or more in a lake.

The adult salmon insistently pursue their course upstream, striving at rapids and falls to surmount these difficulties, and, despite unsuccessful attempts, persist in their efforts until they make their way into the higher levels or are exhausted and die. The erection of a barrier across the stream holds them at such a point, striving day and night to find a way upstream, but never turning back to seek a pathway in some other waters. When exhausted in their efforts to pass the barrier, they may drop back into a quiet, deep pool to rest before renewing their efforts. This may carry them back some distance, perhaps past a fork in the stream. Foerster records that on the Vedder River sockeye once started up the wrong stream at the fork when returning from such a rest. However, they proceeded only a short distance and finally returned to the fork whereupon they turned into the right branch, ascending to the barrier and resumed their efforts to find a way past it.

Incidentally, observations on salmon at barriers and in their efforts to ascend rapids or jump the falls, demonstrate very clearly that their course is not determined by sight, but by definite response to the movements of the water. They may even, when caught in a whirlpool, jump directly away from the fall. They may attempt to surmount the obstacle at some point where no passage is available, but by persistent effort or delaying at times for changes of water level, they succeed at places where, to the observer, success appears impossible on account of the height of the fall or the scanty flow of the stream.

On only one occasion have I seen sockeye during an upstream mi-

gration turn about and definitely swim down stream. In this instance closing the gates at a dam higher up on the stream brought about a sudden drop in water level. Then the salmon caught in a rapids became visibly alarmed by the change in water level, turned about and darted down stream until they reached a deep pool. Once in deeper water their excitement subsided; they began to mill around and when an adequate current was found started once more on the upstream journey.

When a stream is swollen to an unusual extent the movement of an upstream migration may be temporarily suspended. Thus extreme fluctuations of water level either up or down, modify mechanically the response to the current stimulus but even before the normal water level is fully restored the adult salmon start again the active dash upstream.

When the current proves too powerful to be conquered, the salmon do not go back to try another tributary and seek a new spawning ground or find an easier approach to the headwaters. They fight the stream until they perish and the run is destroyed. This was the story of the sockeye at Hell's Gate on the Fraser River.

If by drought or some human interference the river flow is cut off, they linger in pools waiting for the water to come again. If it does, they start up once more. If it does not, they perish from disease. But they never turn back!

As the adult sockeye, struggling vigorously and constantly against the current, swims up stream toward some spawning grounds, its route is so definitely limited that it has only two occasions for exercising a choice that will determine its pathway and its ultimate destination. First, whenever it reaches a junction, it might follow either water route offered. Second, it must sometime bring its journey to an end and choose a spawning ground.

The pattern of a stream system is complex, even though it be only a system of moderate size like that of the Skagit River in the State of Washington. Of the numerous possible tributaries into which the sockeye might conceivably go and of the many lakes and spawning grounds which might be selected, only a very few are actually visited. Furthermore the selection is the same year after year, which some observers have explained on the ground of an instinct; let us consider briefly the result of studies at such stream junctions. Earlier investigators spent some time in testing physical conditions at many junctions. They found that the sockeye did not choose consistently the larger stream, the more rapid current, the clearer water, or the re-

verse. In other words the choice was not determined by volume, velocity, turbidity or any other physical factor which they observed.

After having repeated these older observations without securing any different results, I noticed that in the earlier records statements regarding temperatures were vague, being entered in the record as "water warmer," or even only "warmer." Previous studies on fresh water bodies had involved careful serial observations on temperature and I was aware of the frequent contrast between conditions in air and in water. I began to take temperature records of lakes and stream during the sockeye migrations. Records were made of frequent observations at stream junctions and in spawning areas. Data were secured under all conditions of season, sunshine, wind, light, cloud, stream velocity and volume, melting snow and ice, and other factors that might possibly determine locally in any degree the relative condition of the aquatic environment during, before and after the sockeye run in certain streams.

Before proceeding to discuss examples of temperature influence, let me emphasize the fact that temperature limits are not absolute, nor can they be expressed in figures. There is nothing mathematical in the situation. It is however a very genuine relation. As in many other animals the sockeye recognizes a preferred zone of temperature and doubtless senses optimum, maximum and minimum levels although studies have not progressed far enough to assign even general numerical values to these levels. Furthermore the sockeye in one river do not react favorably to the same temperatures as those which are found in some other river. In general the sockeye in Alaskan rivers are acclimatized to a set of lower temperature levels than those in a Washington State river. Too few rivers have been studied to establish the conditions in many salmon streams or to justify attempts at generalization. Only brief reference can be made here to instances which with others are fully discussed elsewhere.

My own observations have shown definitely that in a considerable series of cases where the branches of a stream differ in water temperature, the salmon universally chooses the one which has the lower temperature. This is in keeping with a long accepted general belief that not only the salmon, but other fish belonging to the same family, are fond of the colder waters. In some cases the migrating salmon show equal definiteness of choice at junctions where no appreciable or constant difference in the temperature of the two streams could be demonstrated. Such a choice is evidently conditioned by some yet undetermined factor. Thus far no instance has been found in which

the migrating salmon at a stream junction have chosen the branch exhibiting at the time of choice a higher temperature than the branch which was not followed; but this statement itself is conditioned by another factor, namely, the quality of the water in question.

Migrating salmon have been observed to pass by without hesitation a tributary, branch, or side stream in which the character of the water was well indicated by its name of Sulphur Creek. A change in the course of the headwaters of Sulphur Creek which eliminated the objectionable feature and left the water clear and cold resulted in diverting salmon from the ancient course into the modified waters of this creek, as it was now pure and lower in temperature than the stream the salmon left. Undoubtedly, other factors than water quality do determine the precise choice of migrating fish at stream intersections.

The second opportunity for choice in the fresh water life of the salmon is afforded at the end of this journey upstream. For the sockeye this upstream journey usually stops in a lake in or near which are the spawning grounds. In the deeper water of the lake they rest, it may be for some weeks, until they are ripe and the time for spawning is reached. To reach this point the sockeye sometimes without stopping pass through a lake in the course of the stream. I have not been able to study conditions in such lakes. The lake in which they finally come to rest offers cool deep water as a resting place during the ripening of the fish. When the sex cells are close to maturity the fish rise out of the deep water and find gravel beds for spawning. These are at points along the lake shore, in the inflowing stream just above the lake or in the outflowing stream near the outlet. Here, again, it is sometimes evident at least, that a selection is made of areas in which the seepage of ground water or the inflow from a colder tributary affords an attractive temperature and at the same time the type of gravel bottom selected for the nest of the fish. In northern latitudes this is an interesting and important choice, since by it the salmon nests are made in seepage waters which do not entirely freeze during the winter, but are kept open by the flow of the ground water. When the fish restrained by an artificial barrier in the stream are prevented from reaching spawning grounds and forced through advancing ripening to release eggs and milt in unsuitable areas, these consistently perish in the long cold winter of extreme northern locations, but eggs of the same fish, normally deposited in higher reaches of the same stream not less subject to adverse atmospheric conditions, survive and yield a new brood in the spring.

The definiteness with which the salmon responds to the temperature

stimulus in finding spawning places is strikingly illustrated in observations I made in Clear Creek, a tributary of the Copper River in Alaska. The fish under observation were red salmon which, as Jordan, Gilbert, and others state of this species, "always spawn in a lake." These observations I have recorded in full in an earlier paper. At the time of my visit salmon were found entering the stream from the Copper River, scooping out nests and spawning along the banks of the creek. Clear Creek does not now have any lake at any place in its course, nor has it any indication of having had a lake at any earlier period. At its junction with the river Clear Creek at the time of my visit was two degrees Fahrenheit lower than the river. The salmon turned into it promptly; the region in which they were spawning was much colder than the stream further up; it was also an area in which a good supply of cold ground water was welling up into the stream through a sand and gravel bottom. No salmon were going upstream beyond this point; neither salmon nor evidence of previous spawning was found beyond that point. The fish fail here to spawn in a lake, the general habit of the species, but they conform definitely in the response to the temperature stimulus given elsewhere.

But other environmental conditions probably aid the salmon in finding its way to the spawning grounds. The sockeye were found to be sensitive in some instances to the quality of the water, as in the case of Sulphur Creek previously mentioned. At another place they refused to enter a trap built of new green boards, though indifferent to a similar adjacent trap of seasoned concrete. Other observations also serve to show the existence of ability to discriminate on the basis of chemical sense (taste, smell).

Sight plays a secondary role, in general, in the activities of fish. The eye is conspicuously rounded and myopic. While this is partial compensation for the density of the medium in which fish live, the eyes are not accurate in interpreting objects. The lures of the fisherman when effectively handled lead the fish to grasp at them or jump for them on the basis of position on the surface, movement, form, or color of a character known in other more desirable objects. The lure creates a transient impression by some feature that produces a particular effect and not by its actual resemblance to the object sought by the fish.

In the choice of the migration route and in the success of the sockeye's journey, sight plays an exceedingly minor part. At a rapids where the salmon seeks by jumping to attain a higher level, it often jumps into a closed pool, onto a bare rock surface, or into a tangle of

shore plants from which it may extricate itself by aimless floundering about, or where it may become trapped and perish. It will jump endlessly at a fence erected to barricade the stream or swim back and forth incessantly seeking an opening large enough for its exit when no jump can top the fence and no search can find an opening.

The migration route cannot even be generally directed by memory or persistence of past images. To be sure in many cases, perhaps in most, the adult fish ascends the same stream which in early life it descended to the sea. But as already noted the young fish going downstream plays along near the shore; the adult swims strenuously in deeper water on its way up the same river. The two pathways are separated by a distance greater than the range of sight. Even if floods have not intervened and produced radical alterations, the river channel and banks have changed every season and with that all the features with which the young fish had come in contact. Whatever aids sense perception gives in determining the way upstream, they are not furnished by the organs of sight.

The influence of light on migration movements of the sockeye is important to consider. In my observations the adults were not found to continue the upstream migration during hours of complete darkness but to rest in deeper holes or in eddies. With the coming of dawn they began to move upstream and in a brief time were vigorously combatting the current and jumping at falls. Later in the morning this activity diminished and ceased on sunlit days, though in cloudy weather it was manifested intermittently during the midday hours. As the sun declined the sockeye again became active and continued through the twilight hours. The period of activity seemed to be limited to the time of diffused illumination and to terminate when the direct rays of the sun were no longer totally reflected from the surface of the water. When in the late afternoon conditions were changed again, then the fish were once more active until the twilight period came to an end.

Some situations are difficult to analyze. Thus, the effect of a heavy rain is seen clearly and very promptly and has been witnessed and recorded by many observers, both on the Atlantic and on the Pacific coast. During a spell of dry weather, which usually is also warm weather, salmon which are at the mouth of a river or have started up, loiter about in deeper pools and appear to have lost the desire to fight the stream. Even a moderate rise in the stream as the result of rain promptly arouses the activity of the fish and they shoot ahead vigorously. Here the stimulation may be due to volume, temperature,

or quality of the water. The first-named cause seems least likely because salmon in nature frequently leave a stream of large volume to continue the migration in one much smaller. But salmon like cooler waters such as one finds in streams after a rainstorm; then also they have fresher waters and changed relations of O_2 and CO_2 tension. This situation is only apparently modified in Alaska where warm sunny weather means rapid melting of ice and snow on nearby mountains. Thereupon the streams carry promptly a daily flood of cold water and the sockeye go up eagerly. This evidences that they also are keen at this period of life to follow the taste of fresh river water. Perhaps both stimuli here favor rapid action. In the complex environment of nature many other factors still remain to be investigated before it is possible to complete the list of the responses which the adult salmon makes to the conditions met during the migration to the spawning grounds.

Concerning the young salmon on its way to the sea, little need be said. There is no choice except to go or not to go, and the movements of the young fish in the downstream direction are slow and apparently hesitating. Young sockeye do not leave the lake in or near which they were hatched until the second spring or even later. As they proceed downstream they feed and play in the small eddies along the shore, dropping occasionally from one level to another as if disinclined to make the venture. But they go over the spillway of a dam involving a descent of 240 feet in just the same way that they drop down a 6-inch step in the rapids. Their vacillating movements contrast sharply with the vigorous striving of the adult to make the ascent of the river. In lakes or reservoirs met on the journey the young keep near the shore; when affected by rising temperature of surface waters they descend into deeper water to find a cooler environment and become trapped by the surface stratum of warmer water which blankets the lake and cuts off access to the outflowing stream. Here in the lake or reservoir they remain "land-locked," cut off from further downstream migration since that can only be carried out if they desert the cool, deeper water levels to enter a warmer current. And that they will not do. So here again is seen the response of the salmon to a temperature stimulus. Those young sockeye which find their way open and reach the sea, disappear in the deeper waters, and thereby pass out of the freshwater region to which this account was to be limited.

These observations show only imperfectly the influences which direct the migration of the adult salmon in the period of its freshwater existence. Further determination of factors or of the extent to which

those illustrated are operative, must await further studies, but from these one may conclude that at least one current belief is not tenable. The fisherman stoutly avers that the adult salmon returns to the very gravels in which it was spawned and hatched, and this view, designated as the "parent stream theory," is widely held by others. But after all, this is no explanation in any sense; it is at most only a convenient expression to conceal lack of knowledge concerning the real situation. At best it assumes the inheritance of a vague, indeterminable influence which does just the right thing at just the correct time to enable the young salmon to find their way from the river mouth to some suitable feeding grounds in the ocean and when the time of maturity is near at hand to retrace their steps to a place known to be fitting for spawning because these particular fish were spawned and started life at that point. A view so indefinite, so loaded with assumptions and so mystical in character, can hardly serve the purposes of scientific investigation however convenient and appealing it may be.

Some of the difficulties in accepting this view deserve at least brief mention here. The correctness of the assumption that the salmon return to a parent stream is at least still open to question. Time does not permit an extended discussion here of the proofs thus far offered. It is my intention to present at a later date a fuller analysis of the various observations and experiments which have been put on record. In my opinion they are not conclusive. While they show that some salmon do conform to the assumption, it is equally certain I think, that all do not. The positive evidence secured has been unduly emphasized and the defects in the proof overlooked. The number of salmon that have been marked or tagged in numerous experiments is very large; the percentage of such that have been recaptured is too small to justify the claim that the record is "conclusive evidence." Let me illustrate what I mean.

A serious-minded student stands at the entrance of a great industrial plant and watches 10,000 employees pour out and swarm down the road which leads to the city. By skill he marks 500 of these and his assistant located at the entrance to an amusement resort on the other side of the metropolis recognizes 10 of the marked men and women entering the resort some hours later. He thinks there were more who passed unnoticed in the crush at the gates he was watching. No one else has noticed any of the marked workers going anywhere else. What conclusion may be reached properly from such data? In their major factors the two cases are strikingly similar and also equally

alike in proving nothing about the habits of fish or men. The same misuse of results from a type of random sampling led a prominent news service into ludicrous and serious error in a political campaign not many years ago.

Apparently no one has yet given attention to the non-conforming element. It is hardly satisfactory to dismiss the case with the statement that sometimes an erratic or abnormal salmon may turn up in the wrong place. The number of such strays is too large to be thus summarily discarded and given no further consideration. Certainly an answer must be sought to some questions which suggest themselves. How large is the part which does not return? Where does this fraction go? What influences that fraction, be it large or small, to go to a new spawning ground and do violence to the inborn, mystical compulsion which the parent stream theory assumes? These questions are difficult to answer. I have felt that some light might be thrown upon the situation by study of the fish in a simple environment, and that is during the part of the life cycle spent in fresh water.

From evidence already published and also outlined in this paper, I feel that there is more reason to believe that in its progress upstream the adult follows a highway through the waters which is marked out from point to point by signs as definite as those which determine for us our course along a road. The highway signs that mark the way through the waters are indicated by temperature, quality of the water, or other physical and chemical features that yield responses as definite as those which we find the fish manifesting under controlled conditions in experimental tanks. The stream which the salmon ascends is not necessarily a home stream, nor is the course of the fish determined by previous knowledge of these waters. The adult seeking the spawning grounds goes upward by constraint along a fixed route and the young wander downstream following necessarily the same course to reach inevitably the waters of the ocean, in which they find conditions for life and growth to maturity.

No assumed mystical impulse makes them go back to a specific place because of their relation to that at the start of their existence. They do, perhaps usually, return to that place because like their ancestors they react in a specific way to the stimuli they encounter on the journey. But they do this only so long as the conditions they meet on the journey remain unchanged. To characterize the situation as due to a parent stream theory is to adopt an empyrical conclusion with all the errors and limitations of empyrical findings. It is to abandon the search for a scientific basis and to lose the greater power over

changing conditions which knowledge of controlling influences will give. If the salmon have been shifted to a new environment or if by any disturbing influences the environmental conditions of the old route have been changed, they go to some other place, a new goal determined by the newly created conditions which they meet. To those new conditions they react in the manner determined by their nerve pattern and not by the ancestral relation to any geographic locality.

No one should lose sight of the fact that even in our rivers and on our coasts natural conditions are changing and these changes give opportunity for distribution of a species into new areas as well as for the origin of possible new species. Some efforts have been made already to explain on such a basis the origin of the Pacific salmon and their wide distribution along the coastal areas of the northern Pacific. A recent species, geologically speaking, its origin may be associated with the period of continental glaciation when it spawned along the shore at the foot of the glaciers. As these ice fields slowly receded it followed up the resulting water courses to find its spawning grounds near the source of the stimulating cold freshwater run-off from the glaciers.

Different species of Pacific salmon do not respond in the same manner to the same stimuli. One conspicuous instance of this has been mentioned: the sockeye young usually tarry over one winter in a lake. Other species of Pacific salmon go more or less promptly down the river from the place they were hatched into salt water and disappear. In variable periods the different species reappear as full grown fish and start upon the freshwater period of their existence. It would be interesting to follow the precise story of these other species of Pacific and Atlantic salmon on the coasts and in the streams of North America. Accounts by older and more recent students of the problem give many details of these stories. The accounts manifest general similarity though differing in details just as the structure of all these forms exhibits a general likeness despite the particular differences also recorded. In both series are to be found evidences of the past that deserve closer attention.

Finally, to make the story complete, the record of the sockeye's life in the ocean must be studied from the same point of view as that taken in the account of its freshwater existence which has just been reviewed. One can hardly doubt that similar environmental stimuli affect it; namely, current, temperature, quality of water, etc. But how does it react? Where do these controlling influences lead it and what brings it, after a period of active growth, back to the shore?

What leads it to enter some river and seek a spawning ground? Surely, not a blind instinct or some inscrutable impulse. In the sea environmental conditions are more variable and change violently and suddenly. Periodically storms modify currents; schools of fish are broken up and scattered widely. Even under generally favorable conditions only 20 or rarely 40% of tagged fish have made the short journey to the places where keen-eyed watchers were waiting for them. Why did this marvelous instinct fail them? Is it not more reasonable to suppose that in shifting waters some were brought into new environmental conditions. In these they responded naturally to the same stimuli that had led their ancestors for unnumbered generations. But those stimuli under the changed conditions lead them to a new goal. Complex as the ocean is, one finds there the same environmental stimuli, mechanical, physical, or chemical, that are in fresh water, and these guide the salmon to some suitable stream for the last phase in its life cycle.

The address was illustrated by a series of lantern slides and figures made from photographs of conditions in nature taken in the course of studies in the field, and by maps of the regions covered. Some further detailed explanations were presented in connection with slides and maps as shown.

PALEONTOLOGY.—*A fossil catfish* (Felichthys stauroforus) *from the Maryland Miocene.*[1] W. GARDNER LYNN and A. M. MELLAND, Johns Hopkins University. (Communicated by C. LEWIS GAZIN.)

A well-preserved skull taken from Zone 12 of the Calvert Formation of the Miocene about three miles south of Plum Point, Maryland, proves to be that of a marine catfish congeneric with the Recent gaff-topsail fish, *Felichthys felis*. This specimen provides the first record of a siluroid from these deposits and indeed appears to be the only complete skull of a fossil marine catfish yet known from North America.

The catfishes (Order Nematognathi) fall into some twenty-five families, most of the members of which inhabit freshwater streams and lakes. However, one large family, the Ariidae, contains about forty-five estuarine and marine genera, which are widely distributed in tropical and sub-tropical regions. The Nematognathi are represented but scantily in fossil records for, although a considerable number of fossil species have been described, the remains upon which most of them are based are too fragmentary to permit of any accurate de-

[1] Received November 18, 1938.

termination of their relations. The greater number of the fossil forms are known from the otoliths alone; others are represented by isolated fin spines or vertebrae; only a few well-preserved crania have ever been found.

In Europe, fossil members of the Nematognathi are known from deposits ranging from Lower Eocene to Pliocene and have been recorded from England, France, Belgium, Germany, Hungary, and Italy. Fossil catfishes have also been reported from the Middle Eocene of Sumatra, from the Miocene of Brazil, and from the Miocene of India. The literature pertaining to these records is to be found in Woodward's "Catalogue of the Fossil Fishes in the British Museum" (1901) and has been adequately reviewed by Leriche (1901). It therefore need not be discussed at length here.

In North America, the group is very poorly represented. Hay (1929) lists only twelve species of catfishes which have been described from deposits of the North American continent. Five of these have been assigned to the Recent genus *Ameiurus*, a freshwater group belonging to the family Ameiuridae. Since these freshwater forms differ rather widely from the marine catfishes it is not necessary to discuss them in connection with the present specimen. The other seven species were all described by E. D. Cope who erected for them a new genus, *Rhineastes*. The remains upon which these species are based are extremely fragmentary, consisting of small portions of skull plates, isolated fin-spines and otoliths. Nevertheless, they are sufficiently complete to indicate clearly that the genus belongs among the sea-catfishes so it has been assigned to the family Ariidae by Jordan (1923). Pertinent information is given in the following list:

R. arcuatus Cope 1873. Mid. Eoc. (Bridger) Wyo. Type, U.S.N.M. No. 3985. Spine and fragments.
R. calvus Cope 1873. Mid. Eoc. (Bridger) Wyo. Type, U.S.N.M. No. 3980. Fragments of cranium, dorsal spine.
R. pectinatus Cope 1874. Mioc. (Florissant) Colo. Type, U.S.N.M. No. 4086. Head and anterior part of skeleton.
R. peltatus Cope 1872. Mid. Eoc. (Bridger) Wyo. Type, U.S.N.M. No. 3984. Occipital-parietal bone and dorsal spine.
R. radulus Cope 1873. Mid. Eoc. (Bridger) Wyo. Type, U.S.N.M. No. 4099. Fragments of skull.
R. rhaeas Cope 1891. Oligoc. (Assiniboia) Canada. Abdominal vertebra.
R. smithii Cope 1872. Mid. Eoc. (Bridger) Wyo. Type, U.S.N.M. No. 3977. Basi-occipital, vertebrae, pectoral spine and articular of mandible.

The type specimens of *R. rhaeas* are figured by Cope (1891) and those of all the other species have been figured by Cope (1884). Ex-

amination of these figures and of the types themselves reveals the reason for the great difficulty which has been encountered in attempting properly to diagnose the genus and as Eastman (1917) remarks, "How closely *Rhineastes*, from the Green River Eocene, agrees structurally with modern species of siluroids cannot be determined, as it is known only by fragmentary remains." In any case, as will be shown, the present specimen shows such well-marked affinities with the modern genus *Felichthys*, that we have no hesitation in referring it thereto.

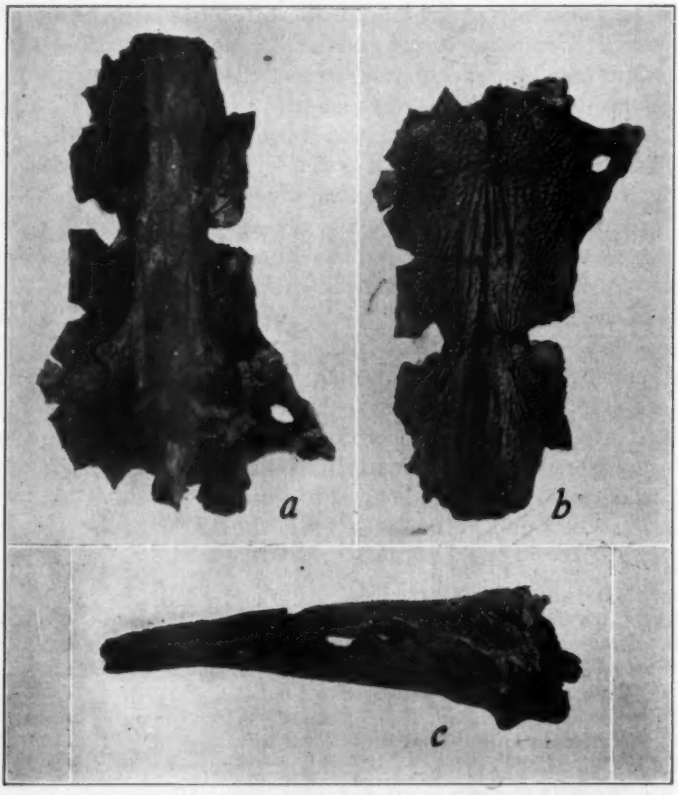

Fig. 1.—*Felichthys stauroforus*, n. sp. Skull, type specimen, U.S.N.M. No. 15746. *a*, ventral aspect. *b*, dorsal aspect. *c*, lateral aspect. All views $\times \frac{1}{2}$.

Felichthys stauroforus, sp. nov.

Type.—U.S.N.M. No. 15746. A nearly complete skull and the left utricular otolith from the same specimen.

Type locality.—Zone 12, Calvert formation of the Miocene, three miles south of Plum Point, Maryland.

Description of skull.—As may be seen from the figures (1a, 1b) the most important deficiency in this specimen is the absence of the most anterior skull bones; the ethmoid, prefrontals, premaxillae and vomer. The right post-temporal and the posterior portion of the supraoccipital have also been lost. All the other bones are practically intact and have suffered no notice-

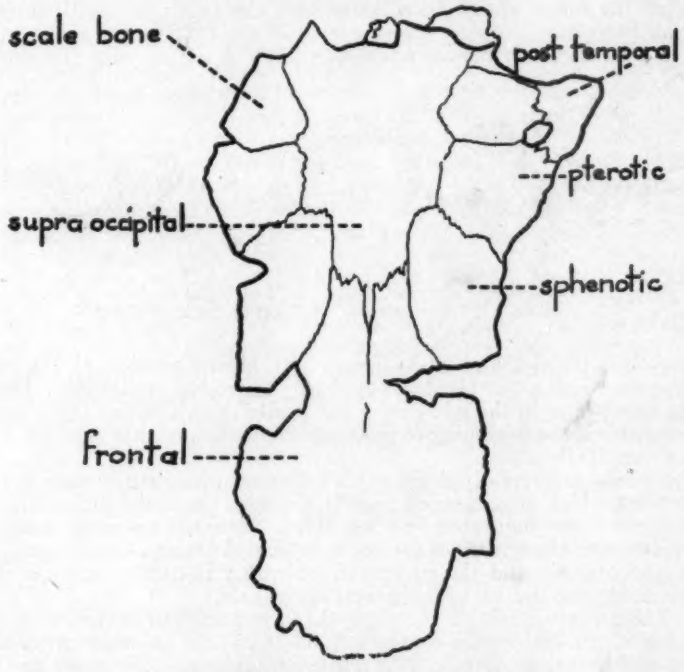

Fig. 2.—*Felichthys stauroforus*, n. sp. Dorsal aspect of skull showing outlines of bones. ×⅓.

able distortion. The sutures of the dorsal surface are well-marked and reveal the outlines of the various plates to be as shown in figure 2. The frontals, which form the anterior part of the specimen as preserved, narrow posteriorly and are separated at their hinder extremities by the narrow anterior projection of the supraoccipital. Two frontal fontanelles are present; the anterior, elongate one measuring 32 mm. The sphenotics which contact the posterior lateral borders of the frontal are rather large and take part in the formation of the lateral edge of the skull. They are in relation with the frontals, the supraoccipital and the pterotics. Their lower surfaces bear prominent arched ridges bordering deep depressions, the points of attachment for the hyomandibular. The pterotics, which lie behind the sphenotics, articulate medially with the supraoccipital and posteriorly with paired bones which apparently represent the "scale bones" figured by Gregory (1933) in

Chrysichthys. Laterally the pterotic forms a part of the lateral border of the skull but, at its posterior lateral end, articulates by a blunt process with an anterior process of the post-temporal. Since the scale bone which lies behind the pterotic articulates similarly with a posterior process of the post-temporal, a foramen bordered by the pterotic, scale bone and post-temporal is formed in the posterior lateral portion of the skull. This foramen measures 9 mm by 5 mm. In the under side of the skull the post-temporal articulates by a long bar of bone with the basioccipital. The supraoccipital, which contacts all the bones above described except the post-temporal, has a thin anterior projection between the two frontals and its lateral margins are indented by a series of curves where the plate is united with the frontals,

Fig. 3.—*Felichthys stauroforus*, n. sp. Left utricular otolith. *a*, inner surface. *b*, outer surface. *c*, diagrammatic section.

sphenotics, pterotics and scale bones. The hinder portion of the supraoccipital is missing but the bone evidently narrowed posteriorly. There is a prominent crest in the mid-line of the posterior half of this bone, but anterior to this is the beginning of the deep median depression in which lie the frontal fontanelles.

The dorsal surfaces of all the skull bones are ornamented with rounded projections which are arranged in definite rows, the individual projections in each row being connected by a low ridge. These rows of projections tend to radiate from the centers of the bones toward the edges. Crossing the scale bone, the pterotic and the sphenotic are rather ill-defined grooves which may indicate the courses of the lateral line canals.

On the under surface of the skull the sutures are ill-defined and slight crushing of the otic region on the left side makes exact description of the bones of this region difficult. The cruciform structure formed by the basioccipital and parasphenoid and the ventral processes of the post-temporals, which is a distinctive characteristic of the skull of the Ariidae and which has been most interestingly discussed and figured by Gudger (1925), is a striking feature in this specimen and suggests the specific name *stauroforus* (cross bearing). At the posterior end of the skull a portion of the mass of bone formed by coalescence of the centra of the anterior vertebrae is preserved. This is fused anteriorly with the basioccipital, the point of fusion being marked by a large, rounded ventral projection. Immediately anterior to this is a foramen leading into the centra of these vertebrae. The ventral process of the post-temporal articulates with the basioccipital just anterior to this foramen. Only that of the left side is preserved. The otic capsules, which house the large otoliths, lie laterally in this region. The deep depressions in the ventral sides of the sphenotics for attachment of the hyomandibular lie anteriorly to the otic capsules. In front of these the skull broadens to a fan-shaped mass, made up of the parasphenoid and the under sides of the frontals.

The skull, as preserved, has a maximum length of 139 mm and a maximum width of 84 mm. Since figure 2 is drawn to scale it is unnecessary to give complete measurements of the individual bones.

Description of otolith.—Since the otoliths of the fishes frequently furnish reliable diagnostic characters it seemed advisable to attempt to recover the otoliths in this specimen. A narrow break already present in the right wall of the cranium made it possible to clear away some of the matrix inside the brain case without injury to the skull. Fortunately the otoliths were found to be present and the left one was removed practically intact. The right otolith has been left within the skull.

In studying this otolith extensive use has been made of Frost's (1925) excellent descriptions and figures. The specimen is of large size (14 mm long and 12 mm high) and agrees with Frost's description of the utricular otoliths of the Ariidae in being conchoidal and biconvex. The inner surface (figure 3a) is rugose with a number of concentric ridges. A posterior process with a slight indentation is present but it has been damaged. The anterior process is rounded. The dorsal rim of otolith is rounded while the ventral rim is truncated posteriorly and indented slightly just behind one of the strong, radiating ridges. The outer surface (figure 3b) has a roughened band along the entire ventral rim with a broad, recurved projection just behind the middle. The rest of this surface represents the smooth sulcal area. The outer surface (figure 3c) is much less convex than the inner. Comparison of this otolith with Frost's figures for members of various families of the Nematognathi immediately confirms the identification of the present specimen as belonging to the Ariidae, for the otoliths in this family are easily distinguishable from those of other siluroids by their large size, their form and the shape and location of the sulcal area. Moreover, among the species considered by Frost the otoliths of *Felichthys marinus* are definitely closest to the present specimen.

The association of this fossil with the genus *Felichthys* on the basis of skull characters is thus confirmed by the structure of the otolith.

As has been pointed out, only a very few well-preserved skulls of fossil catfishes have ever been reported. One of these, however, that of *Bucklandium diluvii*, is especially noteworthy as being the earliest true siluroid known. This specimen from the London Clay (Lower Eocene) of Sheppey, was first figured by König (1825) who regarded it as representing a lizard. Morris (1843) later recognized its piscine nature, but it was not until 1889 that Woodward assigned it to the siluroids. Jordan (1923) places the genus *Bucklandium* in the family Bagridae. A skull from the Upper Eocene of Barton has been described and figured by Newton (1889) who refers it to the fossil species *Arius crassus*, a form previously known only from the otoliths. This specimen is sufficiently complete to be comparable with the skull described in this paper, from which it differs in the absence of the posterior frontal fontanelle, the absence of the post-temporal vacuity and the shape of the supraoccipital.

Ameiurus primaevus, described by Eastman (1917) is perhaps the best known of all the fossil catfishes, since it is represented by a nearly complete skeleton. The origin of this specimen is unknown, though the nature of the matrix indicates that it came from the Green River Eocene of Wyoming.

It is unfortunate that the relations of *Felichthys stauroforus* with the only other known fossil Ariidae from North America, those of the genus *Rhineastes*, cannot be ascertained. However, the fact that in *Rhineastes* the frontal fontanelle is completely closed, may be taken to indicate that the relationship is not close.

The present-day members of the genus *Felichthys* are predominantly subtropical in distribution. *Felichthys felis*, according to Gudger (1916) "ranges as far north as Cape Cod, but is especially common along the South Atlantic and Gulf coasts where it is abundant in brackish waters, for which it seems to have a predilection." Eigenmann and Eigenmann (1890) state that it is found along the Atlantic coast from Cape Cod to Rio de Janeiro. Maryland is thus included in the present range of the genus, but it appears to be most common further south. In view of this distribution of the modern representatives of the group, this record of *Felichthys* from the Maryland Miocene may be an addition to the gradually accumulating evidence, which has been recently discussed by Collins and Lynn (1936), that the temperatures in Maryland during the Miocene were somewhat higher than they are today.

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PALEONTOLOGY.—*Certain pleurotomariid gastropods from the Carboniferous of New Mexico and Texas.*[1] GEORGE H. GIRTY, U. S. Geological Survey.

I. TAOSIA, A NEW GENUS OF HIGH-SPIRED PLEUROTOMARIAS WITH COMMENTS ON TAOSIA COPEI WHITE

The genus *Taosia* is based on *Murchisonia copei* White of which the original specimens were found near Taos, New Mexico, hence the new name.

Taosia possesses a combination of characters not found in any pleurotomarioid shell known to me. Indeed, my ever-helpful and erudite friend, J. Brookes Knight, tells me that he had independently marked down *Murchisonia copei* as typifying a new genus though he has generously yielded me the privilege of describing it. The following characters should be noted:

The long, slender shape; the large number of volutions (possibly as many as 15); the shape of the whorl, which is angulated about midway so that the external surface is sharply differentiated into two zones; the overlap of the whorls to a line well below the carina so that the spire is flanged like a screw; the position of the slitband, midway in the upper zone instead of on the carina; the wide slitband and short slit; the shell composed of two layers; the solid axis without even a false umbilicus; the very tenuous inner lip; the all but complete absence of sculpture. This last statement contemplates a distinction between sculpture and configuration. The carina would come under the head of configuration; the two raised lines which form the boundaries of the slitband would be structural; the delicate lines of growth are not in any true sense sculpture, and the only feature under that head would be the single revolving line on the lower surface.

Taosia is very similar to *Goniasma* in configuration (for example figures 15 to 19), but aside from numerous less significant differences it is distinguished by the position of the slitband which in *Taosia* is situated above the carina midway on the upper surface of the volution, but in *Goniasma* is situated just below the carina on the lower surface. From *Lophospira* also *Taosia* is distinguished by the position of the slitband which is situated not on the carina but above it and it is likewise distinguished by its imperforate axis, by the absence of revolving lirae (on the type species at least) and by other characters.

Taosia copei, though it has never been cited since its original description in 1881, at least in descriptive literature, is not by any means a rare species. I have collected it myself at Taos where it was originally found; it is fairly common in the McCoy formation in Colorado from which specimens were sent to me by I. A. Keyte and it is rather abundant in rocks identified as the Magdalena limestone and exposed in the western foothills of the Frank-

[1] Published by permission of the Director, Geological Survey, U. S. Department of the Interior. Received August 29, 1938.

lin Mountains north of El Paso. The specimens from the Franklin Mountains are not only abundant but in a better state of preservation than those that I have seen from the other localities. I have figured several of them to illustrate the genus and have based the subjoined comments on *Taosia copei* upon them. The rocks at Taos from which *T. copei* was described are, I believe, regarded as Magdalena limestone.

Toasia copei White Figs. 1–7

White's description which accurately covers the salient characters of *Taosia copei* may advantageously be quoted at this point, especially as the species has never appeared in descriptive literature since it was established in 1881.[2]

"Shell slender, apical angle 20° to 25°; full number of volutions apparently about fifteen, all strongly angulated, the angle being more or less distinctly carinated; carina not crenulate; angle situated nearer to the proximal than the distal border of the volutions; spiral band occupying the middle of the outer flattened side of the volutions, of moderate width, inconspicuous, and bordered on each of its sides by a raised line; the remainder of the outer surface of the volutions marked only by fine lines of growth; the proximal side of the last volution marked by one distinct revolving raised line near the carina."

"Length of adult shells from 25 to 30 millimeters."

T. copei is very abundant in my collections from the Franklin Mountains and many of the specimens are in an excellent state of preservation, though none has been observed that is not broken at the apical end and also at the aperture. Observations based on this material enable me to add some characters to those noted by White. His description allows the apical angle a variation of from 20 to 25 degrees; this is true of the common run of specimens but would hardly cover the extremes. The species attains a size considerably greater than that of the types. The final volution may have a diameter as great as 15 mm and an individual of that size is estimated to have been as long as 40 mm.

If specimens the size of the types consist of about 15 volutions, these larger specimens should probably be credited with about two more. The number given in the original description, however, seems to be excessive. The larger of the two types apparently comprises not more than 6 volutions; it is hardly conceivable that 9 volutions are lacking from the broken spire, and only a few volutions can be added at the proximal end if the length of a mature specimen is but 30 mm. Specimens in the present collection, for instance the one represented by figure 2, support the doubt expressed above. This specimen is very similar to the larger type, but is slightly less incomplete. Not more than half a volution is missing at the aperture where the shell has a diameter of 10 mm. The diameter at the broken apex is 2 mm and the actual length 24 mm. The number of volutions is 7. With an allowance for breakage the original length may be reckoned as 30 mm and with an allowance for the broken aperture the number of volutions except for

[2] WHITE, C. A. U. S. Geol. Survey West of the 100th Merid. 3 (suppl., Appendix): XXXI, pl. 3, figs. 10a, b. 1881.

those missing in the spire, may be reckoned as 8. It does not seem likely that 7 volutions are missing from the spire, or in other words that the shell, at a diameter of 2 mm, had accomplished 7 volutions.

The most conspicuous surface feature is of course the carina which on the final volution is situated somewhat below the middle but on the turns of the spire much below the middle. The screw-like shape of the spire is a notable feature of most specimens but the flange of the screw is unsymmetrical, short and strongly oblique on the lower side, long and more gently oblique on the upper. Some variation in shape is occasioned by variation in the direction and in the width of the narrow zone below the carina.

The upper part of the volution, from the carina to the suture above, is essentially flat or faintly concave; rarely faintly convex. It is traversed by two slender raised lines which divide it into three zones of approximately equal width though the upper zone is commonly somewhat wider than the others. The middle zone, which is of course the slit band, varies considerably in width and this entails a variation in the relative widths of all three zones. A third raised line occurs on the lower surface of the volutions. The zone contained between this line and the carina is about equal in width to the zones that occur on the upper surface, being about as wide as the upper one and somewhat wider than the two lower ones, but where the lowest of the three is especially wide, the two zones, one above and the other below the carina, are of equal width. This raised line or slender ridge on the lower side of the volution is apt to be a little stronger than the two that define the slitband, and it is unsymmetrical in shape, much more sharply defined on the side facing the carina than on the side facing the axis. The volutions embrace up to this ridge more or less precisely, so that it is inconspicuous in the spire; an ensuing volution is more apt to project a trifle beyond it than to fail in reaching it. Both conditions are sometimes found in the same specimen.

The surface is practically without sculpture and marked by growth lines alone but these though fine are very distinct. They are, however, slightly less distinct on the slit band than anywhere else. Except for the slitband they show a certain periodicity, for at fairly regular intervals an incised line or stria is somewhat stronger than the rest. They are slightly arched (convex side toward the aperture) and rather strongly oblique fom the suture backward; in the slitband itself, with a sharp change in direction, they form fine regular concave arcs; below the slitband they again abruptly change direction, becoming for a distance gently convex with a slant somewhat forward, though subsequently they straighten out and pass directly to the axis. It is impossible to give the locus at which this change in shape and direction takes place, for the change is at the same time gradual and slight, but in general terms the growth lines are curved and have an appreciable forward obliquity as far as the carina, and are straight and direct from the ridge below the carina to the axis.

The axis is solid; the peristome appears to be folded back upon itself in the axial region without creating an excavation or even an obscure false umbilicus. An inner lip seems to be developed, though commonly it is little in evidence. As a rule the inner lip merely dims or obscures the growth lines within the aperture; on an occasional specimen it makes a more substantial coating. The slit was probably very short. None of my specimens is complete at the aperture, but several appear to be but slightly broken, and even on these the slit is missing; the slit-band can be traced to the broken edge of the peristome.

The shell consists of two distinct layers, a fact which is very conspicuous in many of the specimens from the Franklin Mountains. In these specimens the outer layer has a polished look and a brownish color which, upon closer examination, is found to be a mottling of light brown and black. The growth lines also, though fine, are very clear. Where this outer layer is removed as it is entirely on some specimens and over parts of others, the inner and thicker layer is seen to be lusterless and almost black; it fails to retain or retains but faintly the lines of growth so that on specimens of this sort and on many specimens from other areas, it would be difficult to recognize the slitband as such and consequently the relation of these shells as belonging to the Pleurotomariidae. The type specimens together with other specimens that I have seen from Taos and also the specimens from Colorado are black and show the growth lines less clearly than those from the Franklin Mountains. I have not been able to satisfy myself whether they have lost the superficial layer or are merely not quite so well preserved. The latter explanation seems the more probable one.

Horizon and locality.—Magdalena limestone: Taos, New Mexico (station 6687); McCoy, Colorado (station 8606); 8 miles southwest of Vinton, Texas (station 7067) and other localities in the foothills west of the Franklin Mountains.

II. SOME HIGH-SPIRED PLEUROTOMARIAS FROM LA LUZ CANYON, NEW MEXICO

Rocks that have been classed as Magdalena limestone in various parts of New Mexico contain unlike faunas and may not have been deposited contemporaneously. In the first instance we have the typical Magdalena in the district of that name; in passing up the Rio Grande valley faunas of a different facies are found at Santa Fe and still more different ones at Taos; to the southeast rocks called Magdalena occur in the Sacramento Mountains and others still farther south in the Franklin and Hueco Mountains of Texas. Some of the faunal differences encountered in these different areas will probably prove to be provincial and due to selective environment, but I believe that age differences are also indicated.

In the Sacramento Mountains in La Luz canyon there is a considerable thickness of limestone and shale which seems loosely to have been classed as Magdalena but which contains a fauna different from the typical Magdalena and which is, if I am not mistaken, younger. The fauna in question is dominated by the gastropoda and appears to be related to some of the Cisco faunas of central Texas. It is remarkable for the number and variety of high-spired pleurotomarias such as were formerly classed in the genus *Murchisonia*. These shells came within the purview of collateral studies undertaken in connection with the new genus *Taosia*. I do not recall ever having seen these elongated pleurotomarias in such abundance and was interested, in view of the general similarity of their appearance, to find that they

belong to three distinct genera, *Goniasma*, *Phymatopleura* and *Taosia*. The facts seem of sufficient general interest to be made a matter of record.

Before leaving this subject I may mention that the shale near Tularosa which furnished the cephalopods described by Boese[3] and later by Miller[4] belong to this same series of rocks. Both writers believe, and in my opinion quite rightly, that the cephalopods indicate a Pennsylvanian age. Boese, for some reason, thought that the beds at Tularosa represented the Abo sandstone and on that ground challenged the Permian age of the Abo. The Permian age of the Abo was never too secure and the formation may prove to be Pennsylvanian, but not on the evidence advanced by Boese. So far as I am aware, the typical fauna of the Abo (at the entrance to Abo Canyon) does not contain a single species in common with the fauna of the shale at Tularosa and especially contains none of the cephalopods on which the Pennsylvanian age of the Abo was predicated; and it seems strange to set up a claim that the Abo was Pennsylvanian instead of Permian on the evidence of fossils that did not come from any recognized outcrop of the Abo but were found in rocks at a remote locality and associated with a fauna quite different from the Abo fauna. It is probable that Boese did not know about the difference of faunal association in one sense, but he must have known that none of the species which led him to think that the Abo was Pennsylvanian in age had been identified in an Abo fauna.

Taosia percostata n. sp. Figs. 12–14

Shell of moderate size, very long and tapering, composed of a large number of angulated volutions. Spire much constricted at the suture to which the surfaces of the volutions converge from the angulation. Specimens are not rare, although owing doubtless to their slender shape, all of those examined are fragmentary. The largest seen does not have a diameter at the aperture as great as 10 millimeters. The length, the number of volutions, and other characters which are to be ascertained only from complete specimens, cannot be given.

In the final volution the angulation is situated at about the mid-height and it is reinforced, as of course it is in all the other volutions, by a carina which may be stout and rounded or more slender and angular. The surface between the suture and the carina is slightly concave with a steep descent from above. The surface below the carina is rounded and it has a fairly strong inward slope to its union with the solid columella. In the spire the carina is situated well below the middle of the exposed portion of the volutions, the long slope above having a steep descent and the short slope below passing more strongly inward. The almost flat upper surface of the volution is divided by two revolving lirae into 3 zones which are of about equal size

[3] BOESE, EMIL. Am. Jour. Sci. (4) 49: 51–60. 1920.
[4] MILLER, A. K. Jour. Pal. 6: 59–93. 1932.

though the median one is apt to be somewhat the widest and the one below the suture somewhat the narrowest. The upper of the two lirae may be poorly developed or possibly even undeveloped, especially on some of the earlier volutions. The lower one, on the contrary, is regularly present. The lower surface of the last volution is rather coarsely and strongly striated, being marked by 5 or 6 stout revolving costae, separated by deep and somewhat wider grooves or striae. The volutions embrace to the second spiral costa below the carina, the top of which can be distinguished in many specimens as a slight projection above the suture. Transversely the surface is marked by fine growth lines which tend to form slender fascicles, although these are inconspicuous except on the lower surface where they may be sufficiently strong to produce nodes in places on the revolving costae.

The slitband is, with little doubt, the lowest of the 3 zones on the upper surface, that which is just above the carina. The growth lines descending from the suture have a backward slant and also a backward curve as they near the spiral lira that forms the upper boundary of this zone. Similarly on the lower surface of the last volution the growth lines are gently convex toward the aperture, and have a rather strong backward obliquity to, and apparently onto, the carina. The growth lines, which everywhere else are rather distinct, become fainter near the boundaries of this zone which itself rarely shows any markings at all. The inference is fairly strong from the deflection of the growth lines above and below it, that this zone is, in fact, the slitband, and the inference is strengthened by very rare occurrences there of growth lines that are distinguishable and that make characteristic concave arcs. The upper boundary of the slitband, then, is formed by the first revolving lira above the carina. The slitband does not, on the other side, extend to the edge of the carina but it is there as if abruptly depressed below a narrow elevated rim.

The upper surface of the volutions in this species shows a most deceptive resemblance to that of *Taosia copei*, but in *T. copei* the slitband occupies the median of the 3 zones into which the upper surface is divided, whereas in *T. percostata* it occupies the lowest zone. I am not sure that this should not constitute a subgeneric difference. In other respects, too, the species show marked differences. *T. percostata* has 5 or more spiral costae on the surface below the carina, whereas *T. copei* has but one. It also exposes a broader surface below the carina in the volutions of the spire, and that surface is divided by a stout revolving costa, whereas the corresponding part of *T. copei* is not only narrow but smooth. These differences contribute to make the shape of the shell as a whole markedly different in the two species, the present one being conspicuous for the depth of the spiral constriction at the bottom of which lies the suture. In shape *T. percostata* much more closely resembles the associated species *T. crenulata* and *Goniasma lasallensis*, but all three have such marked peculiarities in one or more details that with identifiable specimens there is no danger of confusion.

Horizon and locality.—Magdalena limestone (?); La Luz canyon, east of La Luz, N. M. (station 6686).

Taosia crenulata n. sp. Figs. 8–11

Shell rather large, very elongate, strongly turreted. Volutions probably 10 or more, though complete specimens are unknown. Spire perhaps twice as high as the final volution. Spiral angle variable, some specimens being very long and slender. Volutions strongly angulated, giving the shell a conspicuously helicoid shape. The angular periphery of the volutions forms a

crenulated carina which may be very prominent and in the final volution is situated at about the mid-height but in the spire divides the visible part of the volutions very unequally—the lower part being much narrower than the upper.

The upper surface of the final volution is essentially planate and descends more or less steeply from the suture. It is traversed by two raised spiral lines defining the slitband. The three zones created in this way are of nearly the same width though the upper zone is apt to be a little wider than the slitband and the lower zone a little narrower. It is commonly somewhat concave spreading out to the carina.

The lower surface of the final volution is about equally divided between an upper part which is flat, depressed, and smooth and a lower part which is gently convex and coarsely costate, both parts descending with about the same inward obliquity until the lower one joins the solid columella. The costate part of the lower surface bears about five rather widely spaced revolving costae, of which the highest is especially large and strong and the lowest small and weak. The upper smooth part of the lower surface appears depressed because of its position between the prominent carina above and the first strong revolving costa below. The volutions overlap to the lower margin of the flat depressed zone, and the prominent costa below it is rarely distinguishable in the spire.

The surface, aside from the two raised lines on the upper surface that contain the slitband and the costae on the lower part of the lower surface (not visible on the spire), is practically devoid of spiral markings. Some specimens, however, develop an inconspicuous spiral line or faint angulation between the slitband and the suture. This feature may make its appearance on the later whorls without being distinguishable on the earlier ones of the same specimen. Sporadically, also, for it has been observed on only one specimen, a few fine irregular spiral lirae may be developed on the upper or sunken part of the lower surface and visible thus on the spire.

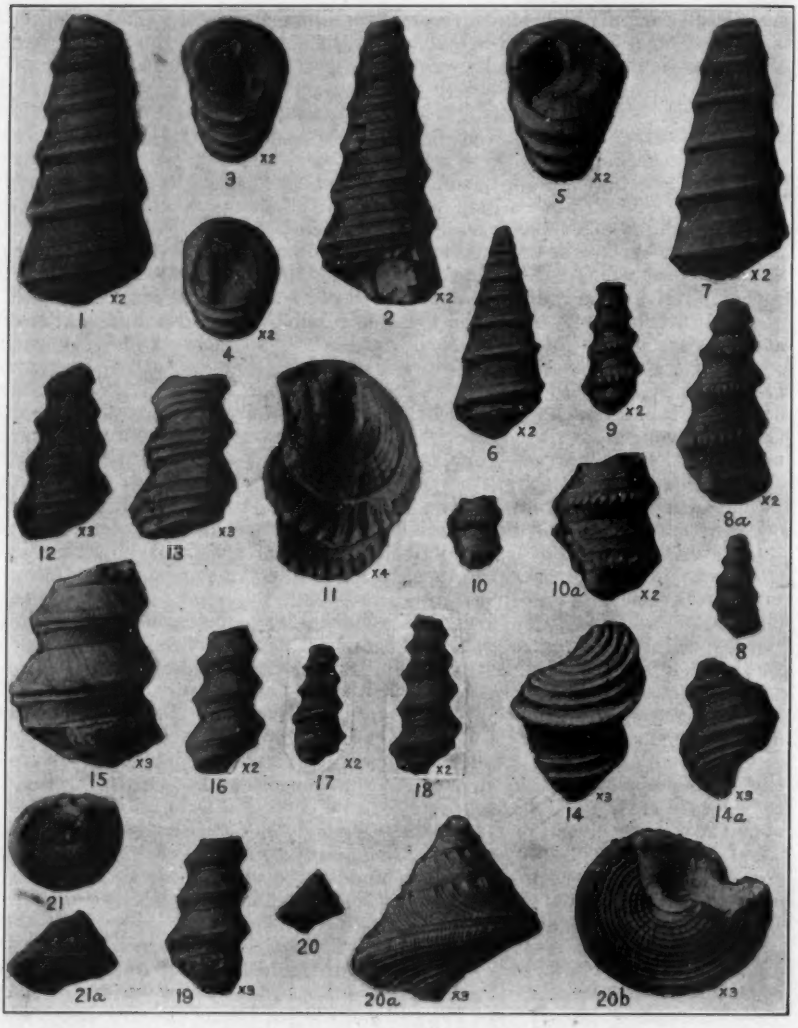
Transversely the surface markings consist of incremental lines which have at first a gentle convexity and a strong backward slant. They are rarely distinguishable in the slitband but where they can be made out they have the usual shape of short concave arcs. From the slitband to the carina they are again slightly convex and have a forward direction from above. On this zone the growth lines are more or less strongly and regularly fasciculate. The fasciculation is but slight at the slitband but near the carina it rapidly becomes very strong, producing the nodes or coarse strong crenulations above described. Below the carina the fasciculation is again greatly reduced, the fascicles being regular but weak.

It hardly seems necessary to specify the distinctive characters of *T. crenulata*. The nodose character of the carina distinguishes it at once from *T. copei* and from *T. percostata;* in addition, the costate lower surface of the volutions distinguishes it from *T. copei* and the position of the slitband from *T. percostata*. *T. crenulata* like *T. percostata* developed costae on the lower surface of the volutions but apparently the development differed materially in detail.

Horizon and locality.—Magdalena limestone (?); La Luz canyon, east of La Luz, New Mexico (station 6686).

Genus **Goniasma** Tomlin

When I propose the generic name *Goniospira* in 1915 the facilities for ascertaining names that were not available through preoccupation were not



Figs. 1–7.—*Taosia copei* White. Figs. 1–5. Five specimens from the Magdalena limestone (?) of the Franklin Mountains. These specimens show the growth lines very clearly. The photographs have been retouched but this character in figs. 1 and 2 has not been exaggerated. The original of fig. 2 has proportions similar to the larger of the two cotypes. Figs. 3, 4 and 5 show the basal surface of the final volution and the imperforate columella. Fig. 5 shows well the revolving lira on the lower surface of the final volution; it can also be seen in figs. 1 and 2. Fig. 2 appears to have a second lira, but the lower one is merely the broken edge of a volution that has been lost. The original of fig. 3 shows the inner lip more clearly than most specimens. It is thin but sufficient to conceal the growth lines along a very distinct line; the deposit is darker than the superficial layer and of the same tint as the inner layer of the shell. If the

what they are today. It seems that *Goniospira* had been used by Cossman in 1895 and by Donald in 1902 so that availing himself of this fact Tomlin[6] in 1929 proposed *Goniasma* as a substitute. The following species, *Murchisonia lasallensis* Worthen, which was made the genotype of *Goniospira* remains the genotype of *Goniasma*.

[6] TOMLIN, J. R. LEB. Malac. Soc. London, Proc. 19: 22–24. 1929.

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basal part of the specimen is regarded as a circle, the inner lip occupies about one-sixth of the circumference from the line of matrix. This character is not brought out in the illustration. Figs. 6, 7. Unretouched photographs of the two cotypes from Taos, N. M., made by J. Brookes Knight, who sent me the prints here published. The cotypes have apparently lost the epidermal layer or at all events do not show the lines of growth at all clearly.

Figs. 8–11.—*Taosia crenulata*, n. sp. Four specimens from La Luz Canyon, N. M. The slitband is situated between the two spiral ridges on the upper surface of the whorls of the spire, the surface lying between the suture above and the nodose carina below. The growth lines slope backward to this zone from above and from below but the concave lines on the slitband are obscure or not visible at all. These features are shown by the originals of figs. 8 and 10. The original of fig. 8 has a faint auxiliary lira a short distance below the slitband and at least 2 fine and faint lirae on the surface between the carina and the suture below. Fig. 11 shows the lower surface of the final volution with its solid columella and spiral lirae. The large spiral lira may be compared to the one similarly placed on *Taosia copei*.

Figs. 12–14.—*Taosia percostata*, n. sp. Three specimens from La Luz Canyon, N. M. These specimens have only one regular revolving lira on the whorls of the spire between the suture above and the carina below and on the original of fig. 13 the carina is not much the larger of the two. This specimen has a faint auxiliary lira which is not well shown by the figure a short distance below the suture. In fig. 14 a corresponding lira is shown, but the regular lira forming the upper boundary of the slitband is hardly visible due to the prominence of the carina and the foreshortening of the surface immediately above it. The growth lines slope backward to the regular revolving lira which marks the upper limit of the slitband; the lower limit is indistinct but is on or just above the top of the carina. The slitband here is above the carina as it is in *Taosia copei* but instead of being situated about midway in the upper surface it occupies the lower third. Fig. 14 shows the strong spiral costae on the basal part of the final volution.

Figs. 15–19.—*Goniasma lasallensis* Worthen. Five specimens from La Luz Canyon, N. M. In this species and genus the slitband has a position corresponding to that of *Taosia percostata*, except that it is just below instead of just above the carina. The growth lines slope backward from below (well shown by the originals of figs. 15 and 16) and apparently come to an end at the spiral costa below the carina which forms the lower limit of the slitband. Its upper limit is indistinct but is situated upon the crest or just below the crest of the carina. The growth lines on the upper surface of the volution bend backward near the carina and can be traced to its crest. The lower surface of the final volution has a prominent angulation or lira somewhat as in *Taosia copei*. Fig. 17 should be more strongly angulated.

Figs. 20–21a.—*Phymatopleura brazoensis* Shumard. Figs. 20–20b. Three figures of a specimen from the Wayland shale, near Graham, Texas (station 7442). This specimen has about 13 spiral lirae on the lateral surface with about 3 additional ones on the nodose ridge below the suture. This is only one of numerous varieties that can be found in a large collection. Fig. 20b shows how the "inner lip" is really a resorbed area. The sculpture at the left comes to an end abruptly along a well defined line at or near the aperture while the smooth area to the right stands at a lower level. Figs. 21–21a. Two views of a specimen from the upper part of the Graham shale at Graham, Texas. In this specimen the nodes are farther apart and the slitband has an auxiliary lira below the median one so that the lower half of the slitband, in that degree, appears to be a part of the under surface.

Goniasma lasallensis Worthen

Murchisonia lasallensis. Worthen, Illinois Geol. Survey, Rept. **8**: 141, pl. 25, figs. 7, 72. 1890. Upper Coal Measures: LaSalle, Ill.

Worthenia? lasallensis? Girty, U. S. Geol. Survey, Prof. Paper **16**: 457. 1903. Hermosa formation: San Juan region, Colo.

Goniospira lasallensis. Girty, Missouri Bureau Geol. & Mines (2) **13**: 356, pl. 30, figs. 7–8a. 1915. Lansing formation: Kenmoor, St. Joseph, Weston, Leavenworth, Lansing, Iatan and Smithville, Mo.

It was perhaps somewhat rash to correct Worthen's description on the strength of my specimens without having seen his, but his description is evidently deficient in details that are apparently shown by his figures as well as being self-contradictory. The corrections which I ventured to make concern the features described in these terms. "On the last volution there is a flattened band below the carina which is bounded below by a slight elevation." The form from Missouri that I referred to *G. lasallensis* and consequently the one on which the genus *Goniospira* was in the final analysis based answers to this description except that in my form both the carina and the elevation below it are double. That is, the carina has a revolving lira a short distance below it and the "slight elevation" is formed by two revolving lirae separated by a narrow groove. In Worthen's schematic figure each of these features is represented by a double line. This suggests that each line represents the top of a ridge and as such an interpretation agrees with the character of my form, it seems to be the correct one. Each pair of lines, however, may be intended to outline a single ridge. One important omission in Worthen's description is his failure to specify the location of the slitband. As the slitband so commonly occupies the carina in the Pleurotomariids, perhaps such a position is implied. The slitband in my form does indeed occur there but it is not situated on the carina which is angular but just below it, its lower boundary being formed by the revolving lira that accompanies it. Worthen's reference to a "flattened band" in the passage quoted above and his failure to mention the slitband in any other way led me to believe that that expression was intended to designate the slitband. This probably was a misconception. Worthen also says, "Neither the flattened band nor the elevation below it extend to the other volutions." This is certainly not true of my specimens and it obviously is not true of Worthen's for it is contradicted by his figures and by another part of his description in which he says that the volutions "are separated by a profound suture." The expression just quoted agrees with his figures which represent the shell as being screw-like in shape, the lower side of each angulated whorl of the spire being nothing else than the aforesaid "flattened band." If the flattened band did not show in the volutions of the spire the volutions would embrace to the carina, and the spire would have smooth sides instead of being made sinuous by a deep constriction. In the form on which the genus Goniospira was based the volutions embrace to the paired lirae on the lower surface.

A species which can be identified with *Goniasma lasallensis* is very abundant at one locality in La Luz Canyon but as the specimens are considerably broken up their abundance is somewhat exaggerated. I have been unable to find any constant difference between the specimens from New Mexico and those from Missouri which I described in 1915. As compared with Worthen's figures of the type, some of them appear to be more slender and many appear to have the constriction in which the suture is situated considerably deeper

so that the sides of the spire are correspondingly more uneven. A few of these specimens developed a spiral thread on the lower surface of the volutions, midway between the slitband and the paired lirae below, on Worthen's "flattened band," that is.

In examining these specimens from New Mexico especial attention was directed to the slitband which is somewhat peculiar in not being as sharply defined as the slitband of most pleurotomarias and in lacking these lunettes or regularly spaced, concavely arched transverse lamellose lines by which the slitband is so commonly distinguished. The slitband is of course distinctly defined on its lower side but not on its upper, except by the angular or, in many specimens, rounded edge of the carina. Its identity, however, is shown by the deflection of the growth lines. As they descend from the suture, the growth lines are essentially straight and have a slight backward slant which, however, increases near the carina, giving them a curved appearance. They are apt to be faintly fasciculate in the upper part and to become somewhat less distinct below though on many specimens they can be seen running out onto the upper surface of the carina. Coming up from the suture below, the growth lines are also distinct to the revolving lira below the carina, but not beyond. They are nearly straight and commonly have a very pronounced backward slope toward the carina. Thus, it will be seen that the slitband as represented by the narrow channel between the carina and the lira below it, often fails to show even growth lines, though where they can be distinguished they have the characteristic shape of concave arcs. As stated above, while the slitband is not bounded on its upper side in the same way as on its lower, and to some extent does not appear to have a sharp boundary at all, many specimens show an incised line on the carina either following the crest of the carina or more commonly following a line just above the crest. Where most distinct this incised line on the carina is similar in appearance to the suture at the bottom of the constriction above, but on a smaller scale. The backwardly-curved ends of the growth-lines can sometimes be traced to this boundary at which they appear to terminate. This feature has been observed on so many specimens that I am inclined to believe it to be a constant one, with this qualification; it is most commonly observed where the carina is thick and rounded as the carina is apt to be on the larger whorls, and it is doubtfully to be observed where the carina is thin and sharp as the carina commonly is in the smaller ones. Accordingly, it would be a character that developed toward maturity. I am also inclined to believe that this incised line marks the real boundary of the slitband. The inference may possibly be drawn that as the shell increased in age the deposits at the slit, which create the slitband, became thickened, but thickened unequally, with the greatest accumulation in the upper part and that the size of the carina was increased by this accumulation.

Locality and horizon.—Magdalena limestone (?); La Luz canyon, east of La Luz, New Mexico (station 6686).

III. PHYMATOPLEURA, NEW GENERIC NAME, WITH COMMENTS ON P. BRAZOENSIS (SHUMARD)

When I proposed the generic term *Orestes* in 1911[6] for certain Pleurotomarioid shells, my investigations into nomenclature, which

[6] GIRTY, G. H. New York Acad. Sci., Annals 21: 136. 1911; also U. S. Geol. Survey, Bull. 544: 155. 1915.

were sincere but not comprehensive, indicated that the name was not preoccupied and the unusual character of the name itself, which was meant to commemorate the work of Orestes St. John, seemed a certain guarantee that it was not. My good friend J. Brookes Knight warned me some time ago that *Orestes* was preoccupied as a generic name and in fact I find that it had been used by Blackiston and Pryer, as long ago as 1880 and again by Redtenbacher in 1906. I take this opportunity, therefore, to propose *Phymatopleura* as a substitute with of course the same species, *Orestes nodosus* as the genotype.

I did not at the time know of, nor have since then come upon, any other species that could certainly[7] be grouped with *Orestes nodosus* except a little known species from Texas described by Shumard as *Pleurotomaria brazoensis*. It seems appropriate in this place to give a supplementary account of *Phymatopleura brazoensis* which was poorly described without illustrations.

In establishing *Orestes nodosus* as a new species, I compared it with *Pleurotomaria brazoensis*, using not only Shumard's description of that species but specimens from the Cisco formation that seemed to belong to it. The species from the Cisco that was employed in those comparisons is clearly the one that Plummer and Moore later figured as *Orestes brazoensis;* and not only is it certain that we are dealing with the same species, but it is almost equally certain that we are dealing with the species which Shumard described and which has lain for so long unrecognized.

With specimens from the original locality and horizon the species can be identified with reasonable certainty but not otherwise. Consequently we find Meek in 1866 and Keyes in 1888 referring to *P. brazoensis* forms which were not only distinct from that species but distinct from each other. Meek's form is now known as *Pleurotomaria intertexta;* that of Keyes, so far as I am aware, is without a name. The figures given by Plummer and Moore show the general character of *P. brazoensis* but they are too small to show the sculpture in detail. Their figures were unaccompanied by a description just as Shumard's description was unaccompanied by figures and as Shumard's description is hard to come by (the work in which it was published being now rare) and as Plummer and Moore's figures are somewhat inadequate, it will be helpful to supply what seems to be lacking in each. Shu-

[7] It is not improbable that the *Pleurotomaria brazoensis* of Meek now known as *Pleurotomaria intertexta*, less probably the *Pleurotomaria brazoensis* of Keyes also belong under *Phymatopleura*. I have not, however, examined specimens of either species. Even if congeneric, however, both of them seem to be distinct from either *P. nodosa* or authentic *P. brazoensis*.

mard's description will be found below and the synonymy which precedes it comprises all the legitimate citations of the species.

Phymatopleura brazoensis (Shumard)

Pleurotomaria brazoensis. Shumard, St. Louis Acad. Sci. 1: 624. 1860. Coal Measures: Young Co., Texas, near Indian Reserve.

Orestes brazoensis. Girty, U. S. Geol. Survey, Bull. 544: 158. 1915.

Orestes brazoensis. University of Texas, Bull. 2132: 151, pl. 22, fig. 16, 16a. 1921. Graham formation (Wayland shale); South of Gunsight (loc. 80.2), Texas.

Shell small, conical, height a little greater than the width; spiral angle 67°; volutions about seven, flat or slightly concave, marked at base with two revolving carinae, between which occurs the band of the sinus; lower carina the larger and rounded; under surface of last volution somewhat tumid in the umbilical region, and flattened towards the periphery; suture depressed, linear; aperture subquadrate; columellar lip deflected above and partially closing in the umbilicus, which is very small; surface of volutions ornamented with from thirteen to fourteen rather strong, filiform striae, which are crossed by sharp transverse striae, giving to the surface a handsome, crenulated appearance; upper margin marked with a row of rather prominent lengthened tubercles; band of sinus moderately broad, excavated, having a single revolving line, and numerous arched transverse striae, corresponding in size to those above the band.

Length, 0.32; width, 0.29.

Formation and locality.—Young County, near the Indian Reserve. Found in bluish-gray marl, associated with *Myalina subquadrata, Chonetes mesoloba, Straparollus catilloides, Fusulina,* and other characteristic fossils of the Coal Measures. Texas State collection.

Shumard, I suspect, intended to write "cancellated" instead of "crenulated" in the above description (see also a comment by Meek) and he leaves the reader in doubt whether the "thirteen to fourteen" striae represents the total number on both the lateral and lower surfaces or the number on only one surface—if so, which? As he says that these striae are to be seen on the surface of the volutions (note the plural) and as only the lateral surface is to be seen on any volution but the last, it seems probable that he was ascribing 13 or 14 striae to that surface alone. This also agrees with his description of the surface as cancellated (if that was actually what he intended to say) for that term is very descriptive of the lateral surface but is much less applicable to the lower surface. Aside from this his description is quite accurate though, as it proved, hardly specific enough to prevent misinterpretation for neither Meek's form nor Keyes' closely resembles true *P. brazoensis.* The description is unsatisfactory chiefly in what is omitted in the way of detail and of the range of variation, for a good suite of specimens such as can be obtained with little difficulty (the species seems to be not uncommon in the general region and at the general horizon from which it was described) discloses that specimens which must be included in the species can differ rather widely. My own observations, which are sum-

marized in the following paragraphs, are based upon about 100 specimens of all sorts.

In the final volution the slitband is broad, oblique, and situated on the periphery which is at about the mid-height. The surface above is oblique and more or less concave, spreading outward near the slitband and ending in a knife-edged ridge which forms the upper boundary of the slitband. The surface, coming up from below, rounds inward slightly to inclose the slitband on its lower side; the slitband thus does not appear to be bounded below by a sharp ridge or lamella as on the upper side. In such specimens the most prominent part of the volution occurs just below the slitband. Sometimes, however, the surface just below the slitband, instead of being sharply rounded and prominent, retreats almost immediately and then the slitband appears to be bounded by a knife-edged ridge below as well as above. The volutions embrace almost to the slitband so that the suture has above it a very narrow and slight prominence, the peripheral region of the preceding volution, and below it a wider and more prominent ridge formed by the upper part of the volution following.

The feature last mentioned varies almost from specimen to specimen. In its most intensified form it is a well marked, broad, rounded ridge with additional elevations at short and regular intervals. In its least development both ridge and nodes are almost, if not entirely, obsolete. This, however, seems to be a condition of old age and it has been observed only on the final volution of a few specimens whose earlier volutions are marked in the normal manner.

The swollen zone below the suture may be broad or narrow and high or so low as to be hardly signalized at all except by the nodes that rise from it. The nodes may be rounded and hemispherical but more commonly they are somewhat elongated and compressed so as to be subangular on top. At the opposite extreme they are very thin and high, as if formed by one of the transverse lirae which, at a definite point below the suture, abruptly becomes thick and prominent. The nodes vary not only in shape but in strength and in spacing. They may be close together or much farther apart, and very conspicuous or very subdued, though always a feature sufficiently pronounced to attract the eye.

The side of the volution between the nodiferous zone and the slitband is marked by fine, regular transverse and revolving lirae of nearly equal strength and spacing, which make a regular reticulate ornamentation. On some specimens the intersection of these cancellating lines is marked by fine raised points, like short spinules, and probably this is a regular feature, though one not commonly preserved.

Three or four of the spiral lirae occupy the swollen or nodose zone below the suture and these are commonly somewhat coarser than the rest; indeed, they may be much coarser. On the remainder of the lateral surface the number of spiral lirae may vary from about 10 to almost 20. Where the number is exceptionally large it may be attributed to the introduction of interstitial lirae, the character of which is occasionally suggested by their smaller size; this tends to create a sort of irregular alternation, though any pronounced alternation in size is exceptional. The difference in scale between the coarsely and finely striated shells is so marked that if extreme examples of each were found without intermediate forms and especially if found at different localities, they would undoubtedly be regarded as belonging to different species. The spiral lirae are commonly slender and rounded, but may be appreciably

stouter with a corresponding difference in spacing in which, of course, number also plays a part. The transverse lirae are thinner than the spiral ones, much like low, vertical lamellae. They may be spaced at the same intervals but may be much more closely arranged. Normally, however, the spiral lirae are numerous and essentially uniform in size, the transverse lirae slightly thinner and spaced at the same intervals, and the result a very regular and very fine cancellation.

Typically the slitband contains a single revolving lira, which may be very slender or relatively stout. Not uncommonly a second smaller lira is developed above or below the median one (as in figure 21a) and in a few specimens an additional lira is developed on both sides of it. The three lirae may be equal in size but more commonly the median one is the largest. Transversely the slitband is crossed at regular intervals by short slender raised lines in concave arcs, which in crossing the spiral lira (or lirae) create very small nodes. The transverse lirae in the slitband are rather commonly spaced at appreciably wider intervals than those on the lateral surface. On some specimens they are irregular in size and spacing, as if by intercalation, and where this occurs they may be more closely arranged than the transverse lirae above.

The basal surface is marked in much the same way as the lateral surface, only more coarsely, especially as regards the spiral lirae. These are on the whole thicker than the revolving lirae of the upper surface and are subject to greater inequality in size. Some of the large ones may be very large and some of the small ones very small and sometimes a more or less regular as well as a strong alternation in size can be observed. In number the revolving lirae may reach 20 or more. Although the lower surface is somewhat broader than the lateral surface and although it may not have many more revolving lirae, it appears more coarsely as well as more irregularly lirate because the lirae are thicker, and, where especially thick, they are rather crowded. A few lirae (4 more or less) on the sharply curving surface below the slit band are generally subequal in size and not so large as the larger ones on the rest of the lower surface while a few near the false umbilicus may attain a relatively enormous size.

The transverse lirae are thin and lamellose like those of the lateral surface and on the same specimen they have about the same spacing on both. A comparison in this item is difficult, however, because the transverse lirae above the slitband have to contract much less in passing upward to the suture than those below the slitband do in passing inward to the axis. Just below the slitband they may be larger and more widely spaced than they are just above it (or on the other hand, essentially the same in both respects), but shortly are reduced to or remain at parity. In crossing the lower surface to the axis they not only become finer but draw together with a tendency to coalesce.

As they converge toward the axis they become more or less strongly fasciculate and give rise to correspondingly large strong nodes on the exceptionally large spiral lirae that occur there.

The characters not touched upon are chiefly generic. The axis seems to be imperforate, though the inner lip is thickened and reflexed to form a small false umbilicus. Instead of an inner lip the surface markings are resorbed so that the surface within the aperture is smooth and slightly depressed below the sculptured surface outside of it.

It was probably this species which I cited as *Pleurotomaria Brazoensis* in

listing the collections made in Missouri by Hinds and Greene.[8] The specimens so identified are fairly numerous but most of them are so incrusted that their characters are imperfectly shown. These and other similar specimens from Oklahoma which I have seen at first appear to be distinct from *P. Brazoensis* by reason of their finer sculpture but they are also of a correspondingly smaller size. The general features appear to be about the same. Specimens from Texas vary so much in their sculpture that some do not differ materially from those from Missouri, and the specimens from Missouri differ from each other in this feature or in that. If the Missouri form is regarded as specifically distinct from the Texas forms there are differences in the content of each which are apparently equal in significance to the differences between them.

PALEOBOTANY.—*The fruit of* Trapa? microphylla *Lesquereux.*[1] ROLAND W. BROWN and EDGAR HOULDSWORTH.

The complete four-parted rosettes of floating, compound leaves as well as the detached leaflets of plants purporting to be a species of water chestnut or caltrop called *Trapa? microphylla* Lesquereux, have long been known from Cretaceous and Eocene strata of the western interior of North America.[2] The surfaces of some slabs of rock, notably those from the Fort Union formation (Eocene) at Burns Ranch, 30 miles down the Yellowstone River from Glendive, Mont., are covered with them. Although much leaf material has been collected from this and numerous other localities in Wyoming, Montana, and Canada, none, until recently, was found with fruit attached. The specimens displaying fruit that are reported here were found in 1936 by Mr. Edgar Houldsworth of Regina, Saskatchewan, Canada, in the Ravenscrag formation (Eocene) cropping out in sec. 4, T. 2, R. 22 west of the 2nd meridian, in the Big Muddy Valley region of southern Saskatchewan.

The finding of these specimens with fruit attached establishes the affinity of numerous detached fruits that were found in previous collections but whose identity remained a mystery. Some of these have been figured and described as *Carpolithus, Viburnum, Nyssa,* etc. It is, however, not our purpose to give a synonymy of these species at this time.

The fruit of *Trapa? microphylla* averages 1 cm in length, is ovoid, the apex being slightly elongate and emarginate or cut at the end

[8] Missouri Bureau of Geology and Mines (2) 13: 305. 1915.

[1] Published by permission of the Director, Geological Survey, Department of the Interior. Received November 21, 1938.

[2] E. W. BERRY has recently summarized the history and knowledge of this species in Geol. Survey Canada Mem. 182: 61–64, pl. 19, figs. 1–11. 1935.

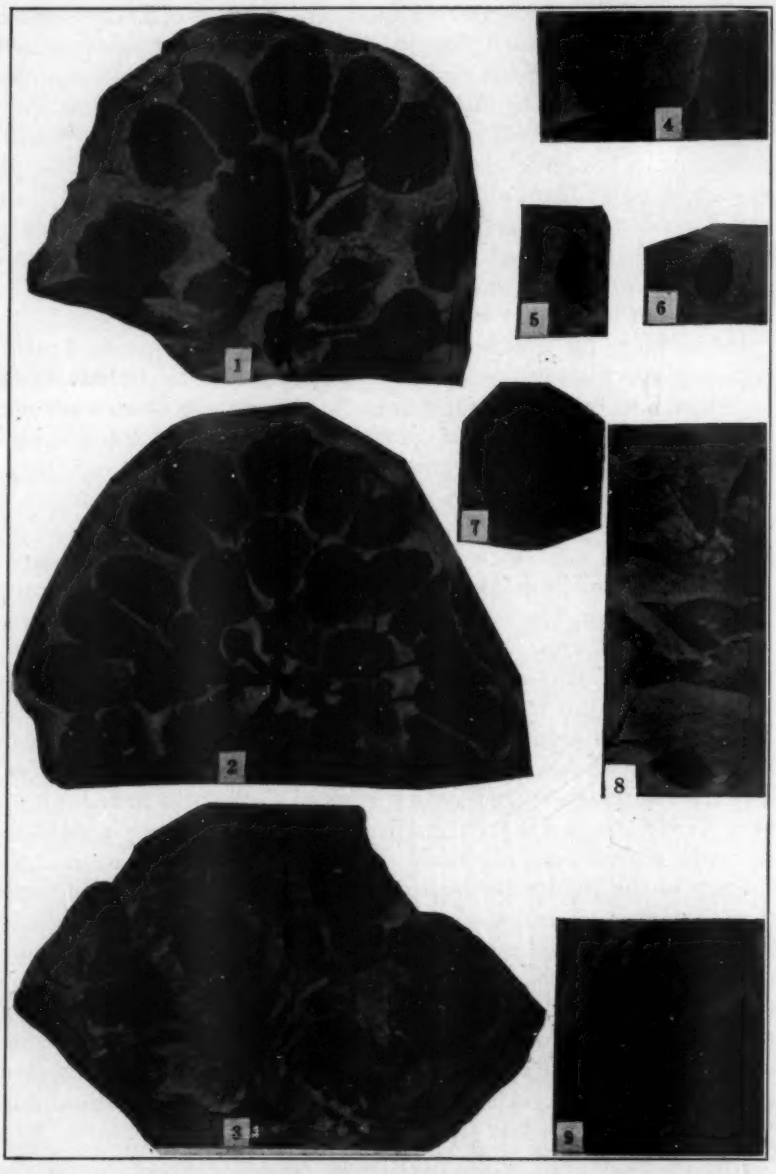
as shown in the better preserved specimens, Figs. 4, 5, 8. The surface displays several prominent, longitudinal bulges and depressions which appear to have been folds that either were present in the living fruit or were initiated at the beginning of fossilization. These fruits were attached by short, stout peduncles to the stem beneath the rosette of floating leaves, somewhat in the same manner as the nuts of living species of water chestnut, *Trapa*. Fig. 1 shows one attached fruit partly overlain by another that is not fully uncovered but presumably belongs to the same plant. It seems probable therefore that *T.? microphylla* produced more than one fruit on a single plant. Nothing is known about the seed or seeds borne in these fruits.

Inasmuch as the fruit here shown to be part of the species *Trapa? microphylla* is without the horns so characteristic of the living species of *Trapa*, and because the leaves of this species are compound, not simple as in living species of *Trapa*, the propriety of the question mark used by Lesquereux becomes doubly apparent. However, these divergences do not necessarily preclude a possible relationship, not too distant, with living *Trapa*, for diversities of foliage and fruit just as great can be matched in many other families of flowering plants. It may be noted that Dawson[3] reports horned nuts called *Trapa borealis* Heer from the same strata on the Red Deer River and Rosebud Creek in Alberta, Canada, that also yield "leaves not distinguishable from those [*T.? microphylla*] described and figured by Lesquereux." Despite this association it is clear now that the horned nuts must have been produced on a different plant, the foliage of which has not yet been found or has not been recognized as that of *Trapa*. Thus far, although several fossil species of *Trapa* fruit have been reported from strata in North America,[4] no foliage positively assignable to *Trapa* has yet been identified.

Some of the Houldsworth specimens, not figured here, yield additional information, not hitherto reported in regard to *Trapa? microphylla*. The quartered rosette of compound leaves that is most commonly the portion found, has for some time been suspected of being the floating part of the plant that appeared on the surface of the water. One of the Houldsworth specimens, and more clearly, a specimen (Fig. 3) from Wyoming shows fimbriated and filiform submerged leaves beneath the rosette of floating leaves. Other specimens indicate

[3] DAWSON, J. W. *On fossil plants from the Laramie formation of Canada.* Roy. Soc. Canada, Trans. 4 (sec. 4): 31, pl. 2, fig. 19. 1886.

[4] BROWN, ROLAND W. *Miocene leaves, fruits, and seeds from Idaho, Oregon, and Washington.* Jour. Paleont. 9: 581, pl. 67, fig. 17. 1935.—*Additions to some fossil floras of the western United States.* U. S. Geol. Survey Prof. Paper 186: 183, pl. 55, figs. 5, 6. 1937.



Figs. 1–9.—For explanation see opposite page.

indefinite lengths of slender, tubular, perhaps noded, stem to which the rosette and fruits were attached. If the broken enlargement at the end of one of these stems was a root or holdfast, the stem could not have been more than 8 cm long, but complete specimens must be had to confirm this point. At any rate these additional facts affirm the inference that *T.? microphylla* was a hydrophyte with morphology and habits comparable to those of *Trapa natans* today.

ORNITHOLOGY.—*A genus and three new forms of birds from Borneo.*[1] J. H. RILEY, U. S. National Museum. (Communicated by H. Friedmann.)

In identifying material collected by Doctor W. L. Abbott and H. C. Raven in Borneo, the following genus and three forms of birds are believed to be unnamed. They may be known from the following descriptions:

Elocincla aenigma gen. et sp. nov.

Type.—Adult male, U. S. National Museum, No. 181562, Klumpang Bay, Southeast Borneo, March 5, 1908. Collected by Dr. W. L. Abbott.

Similar to *Malacocincla* Blyth, but tail shorter than the tarsus, instead of much longer.

The type and only species may be described as follows:

Similar to *Malacocincla rufiventris* Salvadori, but bill and tail shorter.

Description.—Pileum deep neutral gray washed with olive brown; back and outward surface of the wings cinnamon brown, becoming slightly more reddish on the upper tail-coverts; tail mars brown; lores and cheeks deep mouse gray, the auriculars washed lightly with olive brown; throat and jugulum white, the latter with obsolete dusky streaks; chest, sides, belly, and crissum cinnamon; middle of the breast buffy white. Wing, 71; tail, 25.5; culmen, 16; tarsus, 27; middle toe and claw, 22.

Remarks.—The present species is founded upon four specimens, as follows: the type; one male and one female, Kapuas River, West Borneo; and one female, Ritan River, East Borneo. There is some little variation in the four

[1] Published by permission of the Secretary of the Smithsonian Institution. Received November 15, 1938.

Fig. 1.—*Trapa? microphylla* Lesquereux with two fruits, one of which is attached beneath the center of the rosette of floating surface leaves. Ravenscrag formation (Eocene), sec. 4, T. 2, R. 22 west of the 2nd meridian, Saskatchewan, Canada. Collected by Edgar Houldsworth. Fig. 2.—Specimen showing one misshapen attached fruit. Ravenscrag formation. Fig. 3.—Specimen showing fimbriated submerged leaves beneath the rosette of surface leaves. Meeteetse formation (Cretaceous), SE ¼ sec. 10, T. 46 N., R. 98 W., Wyo. Collected by D. F. Hewett. Figs. 4–6, 8.—Detached fruits. Fort Union formation (Eocene), left bank of the Yellowstone River at Burns Ranch, 30 miles northeast of Glendive, Mont. Collected by Lester F. Ward. Fig. 7.—Sketch of leaflet showing venation. After Lesquereux, *The Tertiary flora*, U. S. Geol. Survey of Terr., vol. 7, pl. 61, fig. 16, 1887. Fig. 9.—Small rosette. Meeteetse formation, NE ¼ sec. 2, T. 45 N., R. 98 W., Wyo. Collected by D. F. Hewett. All figured specimens are in the U. S. National Museum.

specimens. In one female there is little white on the breast and the dusky streaks extend forward onto the throat. In two of the specimens the pileum is deep neutral gray without any olive brown wash. The four birds have been compared with five skins of *Malacocincla rufiventris* from Dutch East Borneo and they are remarkably alike in plumage. The latter on the average is a more reddish brown above and the pileum is more heavily washed with brown, sometimes entirely brown. It is remarkable how close the two species resemble each other in plumage and for this reason *Elocincla aenigma* has been overlooked, but the latter can always be distinguished by its shorter tail and bill; it is also somewhat smaller.

The four specimens of *Elocincla aenigma* measure: wing, 66.5–75 (70); tail, 23–25.5 (24.7); culmen, 15–16 (15.5).

The five specimens of *Malacocincla rufiventris* measure: wing, 71.5–75 (73.9); tail, 40–46.5 (43.3); culmen, 17–18 (17.2).

In my opinion *Malacocincla sepiaria* and *Malacocincla rufiventris* belong to two distinct form groups.

Ptilopyga Sharpe[2] (type *Malacocincla rufiventris* Salvadori) is a synonym of *Malacocincla* Blyth.

Iole olivacea perplexa subsp. nov.

Type.—Female, U. S. National Museum, No. 182491, Labuan Klambu, East Borneo, June 28, 1913, collected by H. C. Raven (original No. 909).

Similar to *Iole olivacea charlottae* Finsch, but smaller, the tail a more reddish brown above, the greater wing-coverts and inner remiges edged outwardly with hazel instead of light brownish olive; under tail-coverts ochraceous-tawny rather than ochraceous-buff or colonial-buff. Wing, 78; tail, 72; culmen, 16.

Remarks.—Raven took two females at the type locality on the same day. It may be the hazel edging to the wing-coverts and inner remiges denotes that the specimens are not fully adult, but they are about full grown and it seems hardly likely that there would be any great increment in size. The other female measures: wing, 78; tail, 73; culmen, 16.

Two males of *Iole olivacea charlottae* measure: wing, 88–91; tail, 72–73; culmen, 18–20.5; two females: wing, 82.5–90; tail, 72.5–74; culmen, 18.5–19.

Arachnothera affinis pars subsp. nov.

Type.—Adult male, U. S. National Museum, No. 182150, Birang River, Dutch East Borneo, October 9, 1912. Collected by H. C. Raven (original No. 276).

Similar to *Arachnothera affinis modesta* of the Malay Peninsula, but the lower parts lighter and less greenish yellow; the throat and breast more heavily streaked with dusky; above there is not much difference between the two forms; the Bornean race is on the average more greenish, less yellowish on the upper parts; wing, 89; tail, 55; culmen, 40.

Remarks.—The above race is founded upon three males and two females from Dutch East Borneo. These have been compared with a large series from the Malay Peninsula and Sumatra and they stand right out as described above. A single male of *Arachnothera affinis everetti* from Mount Kina Balu has been examined and *A. affinis pars* resembles it in color but is not so dark below or so greenish above; in size the Kina Balu specimen is somewhat larger; it measures: wing, 95; tail, 61; culmen, 42.5. Seven males

[2] Cat. Birds Brit. Mus. 7: 507. 585. 1883.

and seven females from the Malay Peninsula (the type locality of *modesta* is Malacca) measure: wing, 70–86 (78.2); tail, 39.5–52 (45.5); culmen, 33–40 (35.7). Three males and two females from East Borneo measure: wing, 76–89.5 (82.4); tail, 44.5–57 (49.6); culmen, 35–40 (37.3). Sumatran specimens are slightly more yellowish green above than Malay Peninsula birds and appear to be a little smaller. Three males and three females from Sumatra measure: wing, 72–83 (77.7); tail, 39–50 (44); culmen, 31–35 (32.8).

Arachnothera affinis affinis of Java is much more yellowish above than the Bornean series and below is darker, more grayish; it is rather heavily streaked below like the Bornean form, however. Two males and one female from Java measure: wing, 78–91 (84); tail, 47–59 (52.2); culmen, 33.5–36 (34.5).

Whether *Arachnothera affinis pars* is confined to Dutch East Borneo or not is not known at present, but it seems incredible that such a well-marked form should have escaped naming so long, if it was more generally distributed upon the island.

ZOOLOGY.—*Crabs as food in India.*[1] A. RAMAKRISHNA REDDY, Annamalai University, S. India. (Communicated by WALDO L. SCHMITT.)

Crabs are used extensively for food in India, particularly in all provinces that border on the sea. In Bengal the crabs fished are *Scylla serrata* (Forskål), *Neptunus pelagicus* (Linn.), and *Charybdis crucifera* (Fabr.). *Scylla* is the most important and is very much relished by the Bengalese. The other two only occasionally are brought to market. In Bengal the freshwater *Parathelphusa spinigera* (Wood-Mason) and the esturine *Varuna litterata* (Fabr.) are taken for domestic use by the poorer classes.

Along the coast of Bombay and Sind, *S. serrata*, *Neptunus sanguinolentus* (Herbst), and *C. crucifera* are most frequently caught. The *Parathelphusa* fished in this region is *P. jacquimontii* (Rathbun).

In Madras, *N. pelagicus*, *N. sanguinolentus*, *S. serrata*, *Matuta victor* (Fabr.), and *C. crucifera*, listed in the order of their importance, form a large scale fishery. Here the freshwater species consumed locally are *Parathelphusa hydrodromus* (Herbst) and *P. bouvieri* (Rathbun).

Scylla reaches a large size, 8 to 12 inches in width. In Chilka Lake it may attain a width of a foot and a half! *Charybdis* also grows to a large size, but *Neptunus* not over 8 inches in width. *Parathelphusa* ranges from 2 to 5 inches, while *Varuna* never exceeds 2. *Matuta* grows slightly larger than *Varuna*.

[1] Prepared in response to an inquiry from Dr. Waldo L. Schmitt, of the United States National Museum. I am indebted to Dr. B. N. Chopra, of the Indian Zoological Survey, Calcutta, for assistance in the preparation of this article and also to the Director of Fisheries, Government of Madras, the Director of Industries, Government of Bombay, and the Fisheries Expert with the Government of Bengal. Received December 22, 1938.

In taking *Scylla* commercially[2] a stout bamboo pole is firmly planted on one bank of a creek where the crabs are found. One end of a strong line is attached to this pole. The other is rowed to the opposite bank. From it are suspended a number of smaller lines bearing baits secured to slip nooses. In their efforts to carry off the bait, the crabs are caught in the nooses. Then the line is slowly pulled in and the crabs removed to the hold of the boat, where they may be kept alive for many days. *Scylla* is captured on a small scale by means of an iron hook affixed to a bamboo pole which is used to pull the crab out of its burrow. For the more active swimming crabs, *Charybdis* and *Neptunus*, sieve-nets are used.

In Bengal, large numbers of *Varuna* are obtained for domestic use with circular dipnets like those used for the capture of the soft-shelled blue crab, *Callinectes sapidus*, in America. The *Parathelphusa* fishery of Madras also employs dipnets. In and around Bombay this crab is caught in large numbers in light traps similar to those used in America for hard-shelled *Callinectes sapidus*.[3] *Parathelphusa* is also secured by means of a long stick ending in a swollen knob and provided with a bamboo sleeve which may be slipped down against the knob. This implement is inserted into the crab's burrow. When the crab takes hold of the knob, the bamboo sleeve slips down over its claw, clamping it so tightly that the crab may be successfully pulled out.

In Madras crabbing is an important occupation. A "hook and line" like that employed for catching fish is used. *Hippa* is the common bait. In back waters, floating crab traps are used. Crabs on the west coast are caught in small quantities mainly in cast nets, but also in seines and trawl nets along with fish. In the Gulf of Manaar and Palk Bay wicker traps are common.

Crabs are usually fried or served as soup. From *Scylla* and *Neptunus* only fried dishes are prepared, as follows:

Break the shells of 10 of these crabs so that the animals may be immersed in water, discarding the carapace, gills, and legs. Boil for 15 minutes, after which add 2 tablespoons of chili powder, ¼ teaspoon of cinnamon bark, 2 tablespoons of coriander powder, and ½ teaspoon of salt. Boil for about 5 minutes more. Meanwhile, fry 4 teaspoons of onion chips and one teaspoon of peeled garlic in ghee, gingilee oil, or cocoanut oil until the ingredients turn yellow; also fry separately 6 cloves and 4 pods of cardamon. Add all the fried ingredients to the boiling crabs and continue boiling for 2 or 3 minutes more.

[2] HORA, S. L. *Crab fishing at Uttarbhag, Lower Bengal.* Current Science, 3 (11): 543. 1935.

[3] METCALF, Z. P. *A Text-book of Economic Zoology*, p. 188. 1930.

Fried dishes like the foregoing are also prepared from *Parathelphusa*, but in this case the quantities of ingredients will do for as many as 30 of these smaller crabs.

Soup is generally made from *Parathelphusa* as follows:

Crush 10 adult crabs without discarding either shell or gills. Boil for 15 minutes, after which add 2 teaspoons of pepper, ½ teaspoon of cumin, 1 teaspoon of peeled garlic, and 1 teaspoon of salt, and continue boiling for 20 to 30 minutes longer.

These crab dishes are considered of great medicinal value. Those of *Scylla* and *Neptunus* are used for convalescing malaria patients, also by asthma sufferers. The crab dish seems to act as a specific tonic. *Parathelphusa* soup is used for colds. The extensive use of crabs in such cases cannot be without some justification. In Indian medicine[4] crab curries are recommended for chronic fevers. There may be some mineral salts of medicinal value in the digestive glands of these animals or vitamins which are not destroyed in the cooking process. An investigation of the medicinal value of crabs as food appears to be indicated.

As our Indian crab fisheries have never been properly developed, there is great room for future expansion. The crustaceans fished throughout India perhaps outweigh both in quantity and value the yield of all other fisheries. Prawns rank first, with the crabs a good second. In 1923, crabs and prawns worth Rs. 135,056-14-0 ($33,764±) were sold in Madras.[5] The fishery statistics available for the west coast of the Presidency of Madras show that on an average about 500 maunds[6] of crabs worth Rs. 8,000 ($2,000±) are landed annually on the Malabar and South Kanara coast alone. In Bombay annually 80,000 crabs are caught and sold for Rs. 10,000 ($2,500±). In Bombay and Sind together, 500,000 crabs are caught and sold for approximately Rs. 30,000 ($7,500±) every year. In one year prawns and crabs fished along the Bombay coast sold for Rs. 2,500,000 ($625,000±). For Sind the figures are Rs. 1,500,000 ($375,000±). Large quantities are caught elsewhere in India, notably in Bengal.

If modern methods were employed and the crab and prawn fisheries properly developed, the industry would flourish. Only the Government of Madras has a modern department of fisheries which is giving some attention to the crab and prawn fisheries, but less than their importance warrants. The crabs are of such economic importance

[4] Vastugunadipika. A Telugu Publication, 1914.
[5] MOSES, S. T. Bull. Madras Fisheries, 15 (6): 139. 1923.
[6] The maund, as generally used throughout India equals 32.284 pounds; in Madras, it sometimes may equal only about 25 pounds.

that Dr. B. N. Chopra's suggestions of the formation of an All-India Central Co-ordinating Organization for the Study of the scientific problems connected with our vast inland and coastal fisheries should receive earnest consideration by the Government.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

RECENTLY ELECTED TO RESIDENT MEMBERSHIP IN THE ACADEMY

HARRY S. BERNTON, practicing physician and professor of hygiene and preventive medicine, Georgetown University, in recognition of contributions in the field of protein sensitization.

GERARD DIKMANS, parasitologist, Bureau of Animal Industry, in recognition of his contributions to parasitology, especially helminth parasites of ruminants.

IRVINE T. HAIG, principal silviculturist, U. S. Forest Service, in recognition of his contributions to forest research, particularly on the growth, yield, and natural reproduction of the Western White Pine of the Northwest.

ELMER HIGGINS, chief, Division of Scientific Inquiry, U. S. Bureau of Fisheries, in recognition of his contributions to marine biology as related to the fisheries.

HUGH CURTIS MCPHEE, chief, Division of Animal Husbandry, Bureau of Animal Industry, in recognition of his contributions in the field of genetics of plants and animals.

ELMER MARTIN NELSON, principal chemist, Food and Drug Administration, in recognition of his researches in the field of nutrition and vitamins.

WALTER RAMBERG, physicist, National Bureau of Standards, in recognition of his contributions to mechanics, in particular his researches in the mechanics of structures.

SANFORD MORRIS ROSENTHAL, senior pharmacologist, National Institute of Health, in recognition of his researches on the test for liver function, the pharmacology of arsphenamines and mercury, and the chemotherapy of sulfanilamide.

HARRY WALTNER TITUS, senior biological chemist, Bureau of Animal Industry, in recognition of his contributions to the physiology and chemistry of nutrition, in particular the nutrition of poultry.

EVERETT ELMER WEHR, associate zoologist, Bureau of Animal Industry, in recognition of his contributions to helminthology, particularly nematode parasites of birds.